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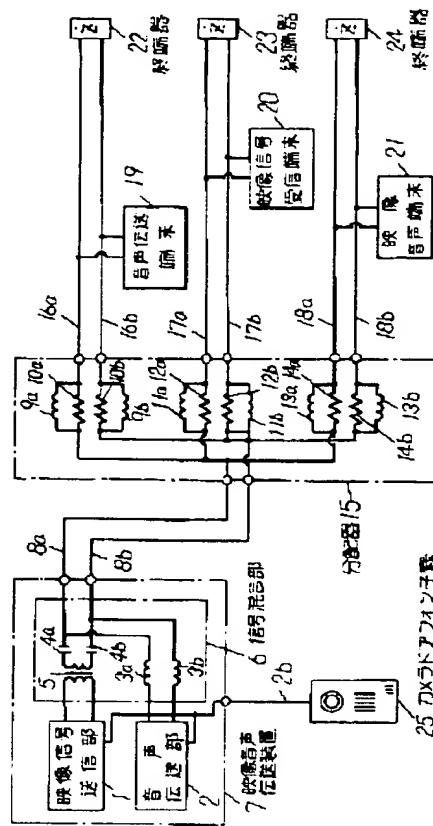
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TITLE : HOME BUS SYSTEM



ABSTRACT : PURPOSE: To transmit an audio signal and a modulated video signal with a pair of twist pair cables in the home bus system and further to mainly and satisfactorily transmit the video signals to the twist pair cables of respective systems by providing a distributor to prevent the reflection of the twist pair cables at a distributing position.

CONSTITUTION: A signal mixing part 6 is provided while being composed of a transformer connected to a video signal transmission part 1 in a video/audio transmitter 7 for simultaneously transmitting the audio signal and the modulated video signal by a pair of twist pair cables, capacitor to pass the frequency band of the modulated video signal, and coil connected to an audio transmission part 2 for passing the frequency band of the audio signal. Further, a distributor 15 for the multiple distribution of a signal transmission line from one signal transmission line is parallelly connected to a resistor for avoiding reflected waves at the distributing position of the video signal having the high frequency band and the coil for suppressing the loss of insertion in the audio frequency band.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(71) Applicant: INLINE CONNECTION CORPORATION [US/US]; 730 North Danville Street, Arlington, VA 22201 (US). (72) Inventors: GOODMAN, David, D. ; 730 North Danville Street, Arlington, VA 22201 (US). DOMNITZ, Robert, H. ; 14 Oakland Street, Lexington, MA 02173 (US). MAHN, Terry, G. ; 1091 Cedrus Lane, McLean, VA 22102 (US).		Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: RF BROADCAST AND CABLE TELEVISION DISTRIBUTION SYSTEM AND TWO-WAY RF COMMUNICATION		
<p>(57) Abstract</p> <p>Systems for communicating video and other information over twisted pair wires that may be actively conducting telephone or data information. An audio/video transmission system for facilitating transmission of video, hi-fi audio, digital, and control signals (such as infrared remote control signals) between different locations in a residence (411a) using existing and active telephone wiring. Simultaneous transmission of signals of each type over active telephone lines is achieved without interference with telephone communications or with the other signal types. Transmission succeeds without requiring special treatment of the video signals beyond RF conversion, despite signal attenuation inherent in transmission over the telephone line media. The fidelity of audio reproduction at the receiving locations is sufficiently high to support the transmission of signals from digital devices without significant loss of audio quality. Multiple video sources and high fidelity audio sources may be tied into the system and selected as desired. Remote control signals generated in one room may be utilized to control video and audio sources in another room without requiring a clear line of sight between the remote control device (492a) and the receiver (419a).</p>		

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RF BROADCAST AND CABLE TELEVISION DISTRIBUTION SYSTEM
AND TWO-WAY RF COMMUNICATION
BACKGROUND OF THE INVENTION

The motivation for the transmission of hi-fi audio signals is an outgrowth of the need to transmit the signals from each entertainment source to every corresponding receiver in a building. (Hereinafter, the term "residence" will be used to generally refer to any building that contains telephone wiring, such as an ordinary single-family home, an apartment, or a commercial building.) There is a need, for example, to transmit the signals from video entertainment sources, i.e. video cassette recorders (VCRs), cable converters, and satellite signal receivers, to every video receiver, i.e., each television. A similar need for communication between audio sources and receivers also exists. In audio systems, the sources include cassette decks, record players, compact disc (CD) players, FM tuners, and turntables. The receivers are the loudspeakers and earphones while amplifiers can be classified as part of either category.

In the classical situation, source and receiver are located close to each other in the same room. To enjoy music or video, however, one does not need to be in close proximity to (or even in the same room as) the signal source. Rather, one only needs to be within visual range of the video receiver or audio range of the audio receiver (so as to be able to see or hear the desired signals) and have an ability to control the sources. Thus, an ability to communicate audio, video, and control signals between rooms will allow one to enjoy music and video using only speakers and a television. While U.S. Patent No. 5,010,399 provided a solution to the problem of transmission of video and control signals, no inexpensive solution to the transmission of hi-fi audio, much less the simultaneous transmission of all three signals, has been developed to

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date.

Hi-fi audio signals can be transmitted across a residence using radio waves as well as by transmission across a wire or other conductive path. Broadcasting 5 signals, however, allows for the possibility of unintended reception outside the residence, and also allows for the possibility of interference from external sources broadcasting at the same frequency. Government regulations covering the broadcast of these signals also present 10 significant obstacles.

Common conductive paths within a residence include power wiring (i.e., wiring that carries 120 VAC, 60 Hz household power), telephone wiring, and coaxial cable. Coaxial cable does not offer a comprehensive solution 15 because it is not available in most residences. It is also bulky, stiff, and unwieldy. Moreover, the signal splitters commonly used in coaxial cabling block transmission between the two downstream ports (i.e., the output ports of the splitters), preventing communication across some of the 20 conductive paths.

Transmission across power wiring is difficult because electrical appliances can impart significant noise onto the wiring network, and because the conductive path is often broken across a fuse box or circuit breaker. 25 Although some systems use power wiring as a conductive path for hi-fi transmission, the systems are relatively expensive, owing to the need for overcoming extremely high noise on the power lines. Even using expensive circuitry, line noise may be so high that it cannot be suppressed in 30 many situations. Moreover, such systems cannot reliably transmit between the differently phased conductors on a 120V residential system, because the conductive paths used by the two phases may only connect far from the residence. Finally, video signals typically cannot be transmitted over 35 power lines with any reasonable degree of quality, so

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simultaneous transmission of television signals and audio is not possible.

Telephone wiring also presents significant difficulties to the transmission of audio signals. Two 5 obvious difficulties are the requirement of avoiding interference with telephone communications and conforming with all regulations that govern devices that connect to the public telephone network. Other difficulties are presented by the transmission properties of telephone 10 wiring. These include the attenuation of the telephone wiring itself, the attenuation caused by junctions in the wiring and connected telephones that drain RF energy from the network, and switching devices that break conductive paths.

15 Devices are available that overcome some of these difficulties to achieve transmission of intelligible audio. Radio Shack™, for example, manufactures a telephone that, when used with an identical cooperating telephone, provides intercom communication at frequencies above the voiceband. 20 These phones work over ordinary telephone lines used in residences. In addition to its limitation as a monaural rather than a stereo signal, however, the sound quality produced by this telephone does not approach that of most hi-fi systems. That is, such a system cannot transmit high 25 fidelity sounds between the telephones in a manner that would maintain the high fidelity at the receiving telephone. The same is true for other systems known to transmit audio information across active telephone wiring. None of these systems, moreover, simultaneously transmit 30 video signals or control signals from infrared transmitters.

While transmission of digital signals within a residence is not currently an urgent need, that situation is expected to change rapidly over the next several years. 35 There are currently several systems, designed to be used in

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office environments, that perform digital transmission over active telephone wires. The catalog of the Black Box Corporation, for example, includes several transmit/receive pairs that perform this function. These devices connect to 5 a digital device to derive a digital datastream that adheres to a particular format, e.g., the IEEE RS-232 standard. This information is converted to a time varying voltage at frequencies above the voiceband of telephones. These signals are then fed to an active telephone wire 10 (i.e., a wire used for voiceband communication) that connects directly from point A to point B without any devices connected in the middle (a so-called "point-to-point" connection). This line typically connects between a telephone and a PBX device. At the end of the line, a 15 receiving device connects to detect the high frequency voltage variations, and convert them back to the original digital datastream.

Because this system transmits data over a point-to-point telephone lines that do not include splits, branches, 20 or telephone devices that are connected in the middle, they may not work over networks with arbitrary topologies and telephone devices connected at random points, features found in the internal telephone wiring of nearly all residences.

25 Distribution of Cable TV signals throughout a residences is an important communication link that also has considerable room for improvement. Despite many technical advances in video transmission that have accompanied the rapid growth of cable TV in recent years, 30 coaxial cabling typically must be installed before the televisions of a residence can receive cable signals. Because most residences did not have this wiring installed at the time of construction, provision of cable TV usually incurs an installation cost. Furthermore, unless this 35 installation is done carefully, which is expensive, damage

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to the trim of the residence (both interior and exterior) is likely. Finally, coaxial cabling is stiff and unwieldy, making it difficult to keep out of sight, and reducing the mobility of connected video equipment.

5 A second category of problems arises when two televisions in a residence are to be provided with cable signals. In this case, a converter box for each television is required unless the televisions are "cable-ready" and descrambling is not needed. Each converter box must
10 include descrambling circuitry, an infrared (IR) detection and interpretation capability (if IR remote control devices are to be used), an ability to detect control signals sent from the local cable company that include the unique address of the converter box, and a power supply, among
15 other things. This can be expensive.

The video transmitters, receivers, and transceivers described in U.S. Patent No. 5,010,399 feed RF signals onto the active telephone wiring and recover signals from the same medium. In particular, these devices are designed to
20 communicate video and control signals at RF frequencies across the telephone wiring. One focus of this application is to adapt these devices and technologies to provide a system whereby cable signals can be supplied less expensively.

25 The provision of cable TV to an apartment building is yet another part of the cable TV distribution system that embodies significant problems. If coaxial cabling is not included at the time of construction, a coaxial cable leading through the entire building must be installed, and
30 a branch must connect between each of the individual apartment units to a point on this cable. This is obviously an expensive procedure, even if easily accessible cabling conduits exist. Furthermore, each branch provides service at only one location within the unit it connects.
35 Extra branches must be installed to provide cable TV

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service at other locations in the unit.

Providing a group of TV signals to various rooms in an office building currently requires a similar amount of coaxial cable installation. The demand for economical 5 video distribution within office buildings is increasing, moreover, because of the increased popularity of video teleconferencing.

The method of distributing cable TV signals commonly used in the U.S. can be called a "one-way branched" system 10 because signals transmitted at the head-end (i.e., at the root or entrance point to the network) spread across to each of the various subscribers by continually splitting into multiple downstream branches. Due to an increase in the popularity of video programming, however, demand for a 15 new system has emerged. Under the new system, sometimes called "video on demand," a subscriber can request a specific program from a library of programs stored at a central location on, for example, video tapes. The signal from this program is subsequently sent to the subscriber 20 from the "head end" of the system. No other viewers can receive the same signal unless they make a similar request.

One method for providing video on demand is to install a high-capacity fiber optic transmission line from the library through a series of residential or commercial 25 neighborhoods. At each neighborhood, all signals targeted for the local residences or businesses (hereinafter, the term "residence" is used to mean both types of buildings unless otherwise stated) are encoded (i.e. scrambled) and then "handed off" at different channels onto the coaxial 30 cable branch that feeds those residences. Thus, each neighborhood has its own individual headend at the point of handoff.

To prevent all residences from receiving each of the signals handed off to their neighborhood, a control signal 35 is sent over the fiber optic transmission line that

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includes the "address" of a converter box in the house of the subscriber who requests a particular signal. This control signal provides descrambling instructions that, because of the addressing, only the targeted converter box 5 will recognize. Under this system, each subscriber receives all signals targeted for his or her neighborhood, but only the program (i.e., the specific video signal) actually requested by a subscriber becomes available to him or her in unscrambled form.

10 The concept of "video on demand" can be considered to be part of a broader communication concept. The broader concept is the widening of communication paths to the ordinary subscribers on the switched public communication network. This would enable subscribers to communicate 15 video signals and other relatively wide bandwidth signals in the same way that they currently communicate voice signals.

The transmission medium that is best suited to provide wider communication paths is fiber optic cables. 20 Indeed, many of the public telephone companies have converted most of their main communication trunks to fiber optics, and have upgraded their switching equipment to handle these signals and their attendant increase in data rates.

25 To bring the wider capacity to an individual site, however, requires one to install a new fiber optic branch from the main fiber optic trunk to each local network (i.e. a house, apartment unit, or a room in an office building), and to switch signals from the trunk onto the branches. 30 Furthermore, conversion from light to electrical signals must take place at the point where the branch reaches the targeted residence. (Conversion is necessary because the communication devices currently found in typical residences and offices respond to electrical signals.) Finally, the 35 electrical signals must be distributed through the house.

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INTRODUCTION

This invention relates to transmitting various signals at radio frequencies across networks of active internal telephone links (that is, telephone wiring which 5 carries telephonic signals within a commercial or residential building) with arbitrary topologies. The disclosures presented herein are partly an outgrowth of ideas and technology disclosed in U. S. Patent No. 5,010,399 which describes methods for transmitting video 10 signals (i.e., visual and sound signals for televisions and the like) and control signals issued by infra-red transmitters across telephone wiring and is incorporated herein by reference.

More specifically, one aspect of this invention 15 represents refinements of the transmission techniques disclosed in the parent application to achieve improved results, particularly regarding transmission of audio signals and digital signals across active telephone wiring. These improvements embody methods for communicating the 20 audio and digital signals across active telephone networks that, in addition to carrying voice information from telephone devices, are also in use as a medium for communication of video and control information. The improvements include devices that simultaneously transmit 25 and receive several RF (radio frequency) signals of varying types through a single connection to a network of telephone wiring. The improvements also include a method for cancelling interference caused by certain telephone devices, and various techniques to increase the total 30 number of channels and the distances over which video signals can transmit.

Another closely related aspect of the invention relates to a system for distribution of cable TV signals over networks of internal telephone wiring. The invention 35 discloses systems for coordinating various transmission and

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reception functions to provide several improvements in video communication over the active telephone wiring of a residence. In particular, a method of distributing multiple cable TV signals without installing new wires 5 (such as coaxial cable dedicated to the cable TV signals) is disclosed. Technology to provide video graphics to televisions and other video devices connected to the internal telephone network is also disclosed.

Yet another closely related aspect of the 10 invention relates to a system for simultaneous two-way communication of video signals and other signals between multiple networks of telephone wiring whose twisted pairs converge together into a single bundle, wiring block, or other common point of access, and a high capacity 15 communication line located at that point of access. Each network includes a set of interconnected, active telephone wires (i.e., a group of wires that create a conductive path for telephonic signals) internal to a house, an apartment unit, or a room in a commercial building. (Such wiring 20 internal to houses, apartment units, or rooms in commercial buildings shall be referred to herein as "local networks.") In the case of houses, the point of common access can be a telephone pole. In the case of apartment buildings, the point of access can be the "wiring closets" found in those 25 buildings. In the case of commercial buildings, the point of access can be the electronic PBX, or "private branch exchange" common to those types of buildings. The high capacity line can be a coaxial cable or an optical fiber. In addition to communication between each network and the 30 high capacity line, communication from one network to another is also provided. The distribution system works just as well when the point of convergence is the center of a computer communications network with a "star" topology, and the wires are the twisted pair wires connecting each 35 individual computer to this center.

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SUMMARY OF THE INVENTION

This invention refines the methods described in U.S. Patent No. 5,010,399 to provide transmission of a broader range of video signals over even longer path lengths with still less susceptibility to interference or distortion due to transmission-induced noise. Moreover, the invention allows high-fidelity audio (such as stereo) signals to be derived from a sound system and transmitted across networks of active telephone wiring without significant loss in the signal properties that determine sound quality (i.e., without any substantial degradation in the fidelity of the audio signals). In addition, the invention enables video, audio, and control signals for the video and audio sources to be simultaneously communicated at radio frequencies over active networks of telephone wiring without interfering with each other or with the telephone voice signals or the operation of telephones connected to the wiring. This allows the user to achieve multiple types of communication (video, audio, and control) with only two discrete electronic devices (i.e., the transmitter and receiver pair provided by the invention and discussed below). It also allows the user to export an entire audio/video entertainment system to a second location in a residence by providing that location with a television and speakers.

Accordingly, one general aspect of the invention is a system for communicating video signals between a source and a destination thereof and that includes a transmitter coupled between the source and a first location on a telephone link that carries voice signals from at least one telephone connected to the link (i.e., an active telephone link), and a receiver coupled between a second location on the telephone link and the destination. The transmitter frequency modulates the video signals from the source in a selected frequency band that exceeds frequencies of the voice signals, and couples the frequency modulated signals

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onto the telephone link. The receiver recovers the frequency modulated signals from the telephone link, demodulates the frequency modulated signals to reproduce the video signals, and applies the reproduced video signals 5 to the destination.

Because frequency modulation (FM) is used, the signal sent over the telephone lines has high immunity to noise and other distortion that are caused by, e.g., the length of the telephone link and splits and other junctions 10 that are typically present on active residential telephone lines. Longer telephone lines between the source (such as a VCR) and the destination (e.g., a television) can be used without degrading television picture and sound quality.

Preferred embodiments include the following 15 features.

The transmitter and receiver each include circuitry (such as filters) for impeding the voice signals on the telephone link from being coupled to the modulation and demodulation circuitry in the transmitter and receiver. 20 This prevents the modulation and demodulation circuitry from "loading down" the voice signals. Likewise, the transmitter and receiver include filters, coupled between the telephone and the telephone link, for impeding the frequency modulated signals from being coupled to the 25 telephone. As a result, the modulated video signals are transmitted over the telephone link with high immunity from telephone loading effects.

A second telephone can be coupled to the telephone link at first location, the second location, or elsewhere 30 on the link. Filtering is used avoid mutual interference between the voice signals and the modulated video signals.

In another general aspect of the invention, the transmitter and receiver communicate audio signals that have a predetermined fidelity level between a source (such 35 as a high fidelity transmitter) and a destination via the

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active telephone link. The transmitter converts the audio signals to a frequency band that exceeds frequencies of the voice signals in a manner that substantially preserves the predetermined fidelity level and couples the converted signals onto the telephone link. The receiver recovers the converted signals from the telephone link, reconverts them from the frequency band to audio signals in a manner that substantially preserves the predetermined fidelity level, and applies the audio signals to the destination (such as an audio receiver or speakers).

Preferred embodiments include the following features.

The audio signals are converted to the frequency band by modulation (such as FM or AM). Similarly, demodulation is used at the receiver to reproduce the audio signals from the modulated signals received from the telephone link. The source produces the audio signals in a pair of channels and the destination is adapted to receive the audio signals in a like pair of channels (so-called left and right channels). Modulation and demodulation are performed separately (using different modulation frequencies within the band) for each channel. The use of different frequencies for the two channels avoids the channels interfering with each other on the telephone link. The receiver also includes circuitry for controlling the amplitude of the recovered signals in each of the channels.

In another general aspect of the invention, the transmitter and receiver are constructed to exchange several different types of signals, for example, video signals, audio signals, and control signals, over the active telephone link. The transmitter and receiver can exchange all of these signals or any subset thereof.

The transmitter converts the video signals and the audio signals to a different frequency bands that exceed

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frequencies of said voice signals, and couples the converted video signals and audio signals onto the telephone link. At the receiver, the converted video signals and converted audio signals are recovered from the 5 link, and the video signals and the audio signals are reproduced therefrom, and applied to their respective destination. The receiver also receives the control signals (which are, e.g., radiated from a source such as a hand-held control unit) converts the control signals to yet 10 another frequency band that exceeds frequencies of the voice signals, and couples the converted control signals onto said telephone link for transmission to said transmitter. The transmitter, in turn, recovers the converted control signals from the telephone link, 15 reproduces the original control signals (such as in the form of infrared energy) therefrom, and applies the reproduced control signals to either or both of the video source or the audio source.

Preferred embodiments include the following 20 features.

The transmitter and the receiver each use bandpass filtering to avoid mutual interference between the video signals, the audio signals, the control signals, and the voice signals.

25 In yet another general aspect of the invention, a television signal that includes an amplitude modulated video component and an accompanying frequency modulated audio component and that is sent by a source thereof over a communication link, possibly with the introduction of 30 noise on the signal, is recovered and applied to a television receiver in a way that substantially reduces noise level. Variations in said amplitude of the audio component of said recovered television signal are measured as an indication of the level of the noise in the video 35 component, and the measured variations are used to reduce

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the level of noise in the recovered television signal.

This aspect of the invention takes advantage of the fact that the audio component is usually close in frequency to the accompanying video component, and therefore is 5 likely to be similarly affected by noise. Moreover, because the audio component is frequency (rather than amplitude) modulated, the amplitude variations are treated as noise with a high degree of confidence.

Preferred embodiments include the following 10 features.

The audio component is separated (such as by bandpass filtering) from the video component. This is possible because the audio component typically has a carrier frequency that is outside of a frequency band that 15 includes the video component. The amplitude of the audio component is averaged over a selected time period. This average provides an accurate indication of the noise level.

The transmitters, receivers, and transceivers described in U.S. Patent No. 5,010,399 are designed to work 20 on any network of telephone wiring where an uninterrupted conductive path exists between any two points. The network may or may not be conducting telephone signals while these components are transmitting RF signals. Loops are allowed. Nearly all residential networks fit this description. The 25 only common exceptions are residences where all jacks are directly connected to a central electronic switch/processor. In U.S. Patent Application 5,010,399, an adapter is described that provides a bypass around this switch, allowing transmission of RF signals to all points 30 of the wiring. The adapter is equally applicable for use with the present invention. The transmitters, receivers, and transceivers use the telephone wiring as a broadcast medium, functioning like wireless communication devices, except that the telephone wiring is the medium rather than 35 the airwaves. Because cable TV signals commonly adhere to

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commercial broadcast standards, such as NTSC, PAL, or SECAM, the video transmitters and receivers of U.S. Patent No. 5,010,399 can be used to distribute individual cable TV channels as well as the video signals from VCRs, video cameras, etc., over active telephone wiring of the residence. In the most straightforward implementation of the systems described in the U.S. Patent No. 5,010,399, a cable converter box connects to one of the video transmitters, and signals tuned by the converter box are fed to this transmitter. The transmitter processes these signals and feeds them to the telephone wiring. This creates a link with the televisions (and other video receivers such as VCRs) that are connected to video receivers on the telephone wiring network. At the same time, remote control units (such as a hand held device that transmits infrared (IR) control signals) usable with the converter box can control the converter box from remote locations through the infrared communication system of the internal telephone network. In this system, the control signals are converted to electrical signals by a video receiver connected to the network and located in the vicinity of the remote control unit (such as in the same room as the user), and the electrical signals are sent from that video receiver over the telephone network to the video transmitter associated with the converter box. That video transmitter recreates the infrared pattern and broadcasts it through the air for reception by the IR window of the converter box.

One important improvement that this invention provides is to unify the cable converter box and the video transmitter onto the same circuit board and within the same housing, and to provide the cable converter box with the capability of tuning and selecting between several signals at once. Such a converter box yields a number of advantages in providing cable TV to a residence. For

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example, the cable converter box is located on or near an outer wall of the residence and the cable TV company only need bring a cable to that location and connect it to the box -- there is no need to carry the coaxial cable further 5 into the residence. The converter box also connects to the telephone wiring from the public telephone network and feeds both the telephone signals and the cable TV signals onto the internal telephone network of the house over ordinary telephone wires (i.e., a four conductor cable that 10 typically includes wires sheathed in red, green, black, and yellow insulation -- the so called "red-green" and "black-yellow" wire pairs). The need to install any coaxial cabling in the house is eliminated.

The methods described in U.S. Patent Application
15 5,010,399 transmit many signals (typically more than 10,
depending on the length and topology of the wiring over the
telephone wiring) at once. Because cable TV companies
typically provide at least forty different signals on their
cables, one way to allow complete freedom in channel
20 selection is to perform the channel selection at the
distribution site, where the coaxial cable connects to the
cable converter box. In addition, the users should be able
to signal a channel change from the location of the
connected television, a location often removed from the
25 site of the cable converter. This invention provides these
capabilities.

Another aspect of the invention also overcomes difficulties that arise when a single cable converter transmits multiple signals over multiple frequency bands 30 and a user wishes to change the channel that is sent over one of those bands. The problem is that the user must have a way of indicating which of the bands is to be used to transmit a different signal. Assume, for example, that the communication system tunes in cable signal A and sends it 35 to all televisions on the internal telephone network at VHF

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channel 8. Further assume that the system tunes in cable signal B and provides it so that it is displayed on televisions at VHF channel 10. A viewer watching signal A on VHF 8 can use the remote control unit in the manner 5 discussed above to key in a request for channel C, but that does not in itself indicate that the newly-selected channel C should appear on VHF channel 8. The RF/video processor of this invention gives the user the ability to specify that the newly-selected channel is to appear on the correct 10 television channel (i.e., VHF channel 8).

Another difficulty that arises when multiple signals are sent -- and that is overcome by this invention -- is the coordination of remote control units. A consumer at a site in the residence at which a television is connected to 15 the telephone network may want to control many different devices with a single control unit. In addition to the television itself, these will often include a cable converter and a VCR that are located elsewhere in the residence. Such a problem can be solved by universal 20 remote controllers, which include or can learn the commands sets of other controllers. Provision of such controllers, in addition to the controller already provided with a television, is an extra expense. Means to control multiple devices with an ordinary controller can reduce this 25 expense, particularly if there are several televisions connected at the remote locations.

To solve these problems the unified cable converter box of this invention includes an interface that connects to the network of internal, active telephone wiring and an 30 incoming coaxial cable (e.g., from a cable television hook-up that originates from outside the residence) that provides video signals. The invention also provides improvements in the video receivers and transmitters that are connected to the internal telephone network and serve 35 as interfaces between the network and various video sources

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(e.g., VCRs) and receivers (e.g., televisions). The interface includes an RF/video processor having circuitry that coordinates all of these units to provide the following results:

- 5 1) Under control of users in the residence, the RF/video processor selects between multiple cable signals and transmits each of the selected cable signals across the internal telephone wiring.
- 10 2) Video receivers connected to the telephone wiring embody improvements over video receivers described in U.S. Patent No. 5,010,399. These improvements will allow the receivers to supply connected televisions with multiple (such as five or more) video signals (selected from the incoming cable TV signals and also from signals provided by other sources on the network, such as VCRs and cameras) within, e.g., adjacent high-VHF or UHF channels. The video receivers also provide the received signals at non-adjacent channels. This is useful when more than five signals are being transmitted across the wiring.
- 15 3) A user can communicate with the RF/video processor via touch tones (i.e., DTMF signals) delivered from any telephone connected to the internal network, or via control signals from any infrared transmitter (located near video receiver on the network).
- 20 4) The RF/video processor also includes circuitry that allows any infrared transmitter to exercise complete control over all infrared responsive devices connected to the internal telephone network.
- 25 5) The RF/video processor further includes microprocessor (e.g., graphics processors) that can, among other functions, display alphanumerics and other images on the connected televisions, providing textual and graphical communication with viewers.

The RF/video processor is designed to work on any network of telephone wiring where an uninterrupted conductive path exists between any two points. Loops are allowed. Nearly all residential networks fit this description. The only common exceptions are residences where all jacks are directly connected to a central electronic switch, but (as discussed above) the adapter

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described in U.S. Patent No. 5,010,399 can be used with this invention to allow communication across those networks.

The RF/video processor distributes several different 5 cable TV signals simultaneously across the active residential internal telephone wiring. As a result, the invention serves the large demand (at least in the U.S.) for the ability to watch different cable channels on different televisions (e.g., in various rooms of the 10 residence) at the same time, and also provides the highly desirable capability of allowing a user to view one cable channel while recording a second.

Thus, in accordance with one aspect of the invention, a system for video signal communication between 15 a source of the video signal located outside of a unit and a destination of the video signal within the unit includes an interface coupled to the source and to an internal telephone link that carries voice signals from at least one telephone connected to the link. The interface receives 20 the video signal from the source, and transmits the received video signal onto the telephone link within a frequency range selected to be different from frequencies at which the voice signals are carried on the telephone link. The video signal is then coupled by the link to a 25 connected receiver, which is adapted to recover the video signal from the link and apply it to the destination.

Preferred embodiments include one or more of the following features.

The unit is a residence such as a house or 30 apartment, or a commercial building such as an office complex. Hereinafter, the term "residence" will be used to include all of these types of units. The source is a cable (such as a coaxial or fibre optic cable) that is linked to the residence and carries a plurality of video signals, and 35 the destination is a television.

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The interface selects at least one of the video signals in response to control information from a user of television and transmits the selected video signal onto the telephone link for recovery by the receiver and application 5 to the television. If the television is adapted to receive the selected video signal in a predetermined frequency band (e.g., a given VHF channel), the interface transmits the selected video signal onto the telephone link at a band within the selected frequency range that allows the 10 receiver to apply the recovered video signal to the television in that predetermined frequency band.

Multiple televisions each of which is connected to the telephone link by a receiver can also be used. In this case, the interface responds to control information from 15 users of the televisions by selecting one or more of the video signals and transmitting them onto the telephone link at different frequencies within the selected frequency range for recovery by the receivers and application to the respective televisions.

20 The interface is also connected to a telephone line that is connected to said telephone link and extends outside of the residence. The interface includes circuitry for passing the voice signals between the telephone link and the telephone line while preventing the video signal 25 from being applied to said telephone line. Bandpass filtering can be employed for this purpose. The voice signals are carried on the telephone link at voiceband frequencies, and the selected frequency range exceeds the voiceband frequencies.

30 In another aspect of the invention, the interface serves to retransmit video signals that are transmitted from a source at one location on the telephone link to a destination located elsewhere on the telephone link. More specifically, the interface receives a video signal 35 transmitted by the source over the telephone link in a

- 21 -

first frequency range that is different from frequencies at which voice signals are carried on said telephone link, and then retransmits that video signal onto the telephone link in a second frequency range that differs from both the 5 first frequency range and the frequencies of the voice signals. The retransmitted video signal is coupled via the telephone link to a receiver that recovers the video signal and applies it to the destination.

Preferred embodiments include the following 10 features.

The destination is a television located together with the source within a residence. The interface is also adapted to receive a second video signal from a source located outside of the residence (such as an incoming cable 15 TV line). The interface transmits the second video signal onto the telephone link in yet another frequency range that is different from the first and second frequency ranges and from the voice signal frequencies. The second video signal is coupled via the telephone link for recovery by the 20 receiver, which in turn applies it to the television.

Another general concept that this invention provides is the use of active telephone wiring (i.e., wiring that is also used for its normal purpose to carry telephone signals) as the transmission line leading from a main cable 25 trunk (which is coaxial cable or fiber optics) to the individual subscribers. This significantly reduces the complexity and expense normally associated with cable TV wiring, above the reduction provided when the main cable trunk carries signals all the way to the subscriber. A 30 major advantage of this wiring over coaxial cable is that nearly every residence (such as an individual house or an apartment unit in an apartment building) has one or more phone lines, each including at least one twisted pair (e.g., the red-green pair; typically, a second twisted pair 35 of black-yellow wires is also provided) leading to it from

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the telephone company trunk line. A second advantage is that signals applied to the telephone line are available at every telephone jack, rather than at a single coaxial outlet.

5 Thus, a general aspect of this invention is a system that provides video signal communication between a source of the video signal and a plurality of units that include destinations of the video signal and that includes an interface coupled to the source and to telephone lines,
10 each of which serves at least one of the units and carries voice signals to and from one or more telephones coupled to the telephone line at said unit. The interface receives the video signal from the source, and transmits the received video signal onto at least one of the telephone
15 lines in a selected frequency range that is different from frequencies at which the voice signals are carried on that telephone line. This causes the video signal to be coupled to a receiver which is connected to the telephone line at the unit served by that line and is adapted to recover the
20 video signal from the telephone line and apply it to one or more of the destinations at the unit.

Preferred embodiments include the following features.

The source is a cable (e.g., electrical or fibre
25 optic) that is linked to the interface and that carries a plurality of video signals. The destinations are, e.g., televisions. The units can be residences (such as individual houses or apartments in an apartment building) or offices in an office building. Hereinafter, the term
30 "residence" will be used for all such units.

The interface is adapted to select one or more of the video signals in response to control information from a user or users of televisions at any residence and transmit the selected video signal or signals onto the
35 telephone line that serves that residence for recovery and

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application to one or more televisions in the residence. If multiple video signals are selected for a given residence, the interface transmit the video signals onto the telephone line that serves that residence at different 5 frequencies within the selected frequency range. This prevents the selected video signals from interfering with each other.

The interface can select the same video signal for multiple residences and transmit the video signal onto the 10 plurality of telephone lines that serve those residences. Further, the same video signal can be sent over the telephone lines at the same or different frequencies.

At least one of the residences includes an internal telephone link to which its receiver and at least one 15 telephone is connected. The internal telephone link is connected to the telephone line that serves that residence, either directly or via a local interface. The local interface amplifies video signals received over the telephone line and couples them onto the internal telephone 20 link. This helps compensate for attenuation that typically occurs during transmission to the local interface, thereby increasing the quality of the video signals recovered by the receiver.

At least one of the residences includes a source 25 (e.g., a video camera) that applies a second video signal that applies said second video signal onto the internal telephone link in a second selected frequency range that is different from both the frequency range selected by the interface and the frequencies at which the voice signals 30 are carried on the telephone link. The local interface amplifies the second video signal and couples it onto the telephone line that serves the residence to cause the second video signal to be coupled to the interface. The interface, in turn, transmits the second video signal to 35 the source.

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The interface is coupled between the telephone lines and corresponding public telephone lines (which carry voice signals at voiceband frequencies) that serve the residences. In one embodiment, the interface couples the 5 voice signals between each public telephone line and each telephone line at voiceband frequencies, and the selected frequency range exceeds the voiceband frequencies.

In another embodiment, the interface converts the voice signals on the public telephone lines to a frequency 10 range above voiceband frequencies before coupling the voice signals onto the telephone lines for transmission to the residences. In this case, at least a portion of the selected frequency range for the video signals includes voiceband frequencies. The local interfaces at the 15 residences reconvert the voice signals to voiceband frequencies and change the frequency of the video signals to a frequency band above voiceband frequencies before coupling the voice signals and the video signals onto the internal telephone link.

20 A possible drawback of using active telephone wiring to transmit video signals (e.g., cable TV signals) to the residence according to this aspect of the invention is that the number of signals that can be effectively transmitted may be more limited. This, however, can be solved because 25 only a very limited number of signals are typically useful at a single time. One recommended solution is to locate the channel selection device at the point of connection to the main telephone trunk (also called the "point of convergence" of telephone lines from multiple residences) 30 and send only the selected video signals to each residence via the telephone line.

This arrangement can actually achieve extra economies if telephone lines from several subscribers converge at one point, as they do in apartment buildings 35 and sometimes on telephone poles or pedestals. One economy

- 25 -

that can result is that the channel selection electronics for several subscribers can be embodied in a single device, thereby reducing hardware cost. The second economy is that scrambling of the signals is not necessary. Signals not paid for by a subscriber will simply not be handed off onto the telephone lines leading to the residence of that subscriber.

Ordinarily, piracy would be a problem because it is easier to "tap" an RF signal from a twisted pair, which is unshielded, than from a coaxial cable. Furthermore, a "tap" onto a twisted pair is less obvious than a tap onto a cable. Because the signals are "handed off" from a point of convergence, however, only specifically selected signals emerge from that point, and there will ordinarily be less than three video signals on any individual wire (as described in more detail below). By protecting that convergence point, therefore, fewer signals are available for piracy than in the case where coaxial cables reach all the way to the television. Because easy, surreptitious access to the convergence point will not be available when the point is on a utility pole or in the basement of an apartment building, piracy from the twisted pair distribution system of this invention is even more difficult.

The general principles and techniques described in U.S. Patent No. 5,010,399 include some of the ingredients useful to enable converging telephone lines to carry video and other signals from a point of convergence to the individual local networks (i.e. houses, apartment units, rooms in office buildings) in addition to carrying the telephone signals. Problems can arise, however, due to the unusually long path length of the wire branch leading between the point of convergence and the internal telephone network within a residence. Other problems can arise because the wire pairs from neighboring subscribers are

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often tightly bundled near the point of convergence. This may cause a signal from one wire pair to be picked up by a neighboring pair in the bundle, causing interference. Finally, provision must be made for selection of cable TV channels from within each residence. One of the objects of this invention is to overcome these problems.

Using active telephone wiring as the transmission line for wideband signals (e.g., cable TV signals) leading from a main telephone trunk line to the individual subscribers can also improve upon communication systems other than those used to distribute ordinary cable TV. One example is the "video on demand" system described above. A shortcoming of the typical video on demand system is the coding and decoding (i.e., scrambling and unscrambling) that must be provided at each end of the transmission line. Another drawback is that the excess capacity on cable trunks carrying cable TV signals is typically very limited. If, for example, a cable TV franchise provides signals up to cable channel 63 (which extends between 462 Mhz and 468 Mhz), the "video-on-demand" signals are restricted to the frequencies above that. Using higher frequencies may be undesirable because the attenuation of the cable increases with increasing frequency, and most cable converters are not designed to extend that high. If the existing cable can transmit signals up to, for example, 600 Mhz, then only 132 Mhz, or the equivalent of twenty-two 6 Mhz AM channels, are available above channel 63 at each neighborhood. In this situation, at most 22 houses per neighborhood can receive video on demand.

Telephone wiring from a centralized location (such as the point of convergence discussed above) can be useful because it can replace the coaxial cable as the conductor leading from the cable trunk (e.g., the high-capacity fiber optic line) to the individual residences. One advantage of telephone wiring is that it provides a dedicated path from

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the point of convergence to each subscriber. This means that signals on the optic fiber line that are "handed-off" onto an individual wire pair transmit to only one subscriber. This eliminates the need for scrambling which 5 is otherwise necessary when many subscribers receive a signal (such as over a shared coaxial cable TV network) that only a limited group of them pay for.

A disadvantage, mentioned above, is that such a point of convergence at which conductors lead to a large 10 number of subscribers is not always nearby. If some of the subscribers are a great distance from the convergence point, the attenuation of transmission may be too severe to allow reliable communication across the twisted pairs that comprise the telephone line.

15 This problem is less severe in the case of the residential units in an apartment building. Because these buildings typically consist of many units whose telephone wire pairs usually converge at a nearby point, such as when a "wiring closet" is provided for each floor, their 20 telephone lines are particularly good candidates for providing this type of communication. Usually, there is a point in the basement of such buildings where the wiring from all units on all floors converges.

Commercial buildings also include locations where 25 many telephone lines converge. Often, the individual wires leading to the various rooms of the building converge at what is called a "PBX," or private branch exchange. Such an exchange is provided because considerable communication between rooms is required that is not, of course, 30 economically provided by the public telephone exchange.

As mentioned earlier, the popularity of teleconferencing has created a demand for video distribution within an office setting. Often, videoconferencing allows for a group of workers in a 35 building to monitor a conference at a remote location.

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This requires one-way communication of video. Other forms of video conferencing, however, require two-way video communication. Using telephone wires for these purposes is more complicated, of course, because at least two video signals must transmit in opposite directions. One solution, proposed herein, is to use more of the frequencies, or spectrum, available on each wire pair. Another is to use a different wire pair in the same bundle leading to each office, if it is available. Each of these causes special problems, as will be described herein. One of the objects of this invention is to overcome the problems associated with two-way communication of video across the telephone wires in an office building.

Because of the considerable communication demand between rooms in an office setting, a demand has also arisen for two-way video communication between rooms in the office. A difficulty in using the telephone wiring for transmission of video across that setting is that the conductive paths between the various offices are broken by the PBX. In U.S. Patent No. 5,010,399, a technique to provide a high frequency "bridge" between the various wires leading to a PBX was described, thus making the various wires appear, at high frequencies, as a single conductive path. In this application, that technique is expanded upon to provide switching of video between offices, and simultaneous communication of more signals.

In many office buildings, the telephone wiring is not the only network of twisted pair wiring that extends to each office and converges at a common point. Over the past several years, common communication networks that connect personal computers, known as Local Area Networks or LANs, have begun to use twisted pair wiring for their conductive paths. In the typical configuration, a digital electronic device serves as the "hub" for such a system, and a separate twisted pair wire connects from this center to

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each of the computer nodes. Transmission of video across this medium involves the same problems encountered in transmitting across a PBX system. Additionally, extra difficulties are encountered because the signals that 5 "naturally" transmit across the system, i.e. the digital computer signals, occupy a much wider band than telephone signals. In this application, the technique for communication across a PBX is expanded to provide the same capabilities for wiring networks that provide the 10 conductive paths of a computer local area network (LAN).

In addition to video distribution to houses and apartment units and video communication within office buildings, there is a fourth communication system that can be improved upon by distributing video signals over 15 multiple pairs of telephone wires. This system is the main public telephone network itself. The copper wires of this network are currently being replaced by fiber optics because these lines can carry much more information. Increasing the communication capacity to an individual 20 residence using current technology requires installation of a fiber optic cable spanning the entire distance from the "local exchange" to the residence. The improvement described herein is the result of using the existing copper wires to communicate video and other signals over 25 approximately the last 1000 feet of this link, i.e. from the main optical fiber trunks to electronic devices in subscriber facilities. This eliminates the need to install a new communication line between each residence and the main trunk. It also eliminates the need to adapt each 30 electronic device in a residence to receive optical signals.

A new development in video communication colors the entire concept described so far. The new development is the advent of techniques that digitize and compress 35 standard commercial video signals (such as NTSC or PAL) in

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real time, without reducing information content, so that the resultant digital bitstream has a data rate that is slow enough to be expressed as an analog waveform in a remarkably narrow channel. This development presents the 5 possibility that considerable programming will be transmitted in this form in the near future.

Accordingly, it is seen that the present invention provides a technique for one-way distribution of signals of a general nature that require bandwidths much wider than 10 the 3 KHz voiceband currently in use. These signals are transmitted to multiple local networks of active telephone wiring, (i.e. the telephone wiring systems of several houses, apartment units, or rooms in an office building) from a signal source at a location where the active 15 telephone wires leading to the residences converge. In the typical application this signal source will be a "tap" into high capacity communication link such as a fiber optic transmission line or a coaxial cable.

The interface provided by the invention includes a 20 transceiver/switch located at the point of convergence. This device replaces the existing interface between the public telephone network (i.e., an ordinary telephone trunk line) and the telephone lines that lead to the individual residences. (These telephone lines are referred to below 25 as "extended twisted pairs".) Typically, the existing interface will be a simple "punch-down" panel that provides electronic connections between the extended pairs and the pairs that are part of the trunk line. The transceiver/switch receives multiple signals (such as 30 several channels of cable TV signals) from the high-capacity communication link such as a coaxial cable or fiber-optic line, and selectively switches these video signals onto the individual phone lines, together with the phone signals. Means are provided at each individual 35 network (i.e. the internal telephone wiring of each

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residence) to receive and separate these signals.

In addition, the invention allows each subscriber to control the signal selection by the transceiver/switch in situations in which a large group of signals on the high capacity communication link is made available for selection by any subscriber. Control (e.g. channel selection) is established by sending signals from a local network to the transceiver/switch over the extended twisted pair telephone lines, e.g., in the reverse direction from the direction of transmission of the selected video signals. A particularly appropriate application for such a system is as an alternative method of distributing cable TV service.

The invention also provides two-way communication of signals of a general nature with the high capacity transmission line. This allows the user to transmit wideband (e.g. 5 Mhz) signals of an arbitrary nature (such as video signals and high data rate computer signals) over the extended twisted pairs from the user's residence to the transceiver/switch, so that the transceiver/switch can add them to the high capacity transmission line for communication with, for example, a receiver at the point where signals transmitting in the "forward" direction originate (e.g., the video library discussed above.)

The invention further provides two-way switched video communication between the local networks (e.g. the rooms) in office buildings and in other buildings that have requirements for two-way communication.

Moreover, all of the communication capabilities discussed above can (and preferably do) use networks of twisted pair wiring that are also used for computer communications.

The communication techniques of the present invention can be adapted to provide the same capabilities when the signal source at the point of convergence provides video signals expressed as analog signals representing

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compressed digital bitstreams.

It is important to note that this invention provides the video signal communication capabilities described above while preserving all of the features of the pre-existing 5 telephone and computer communications. Thus, interference on the telephone lines between ordinary telephone communications and the selected video signals is avoided.

As discussed above, the interface includes a transceiver/switch that is connected to multiple pairs of 10 telephone wiring and is interposed between telephone wire pairs from the local telephone exchange (the trunk line) and the extended telephone wire pairs leading to separate local networks of telephone wiring. The transceiver/switch also connects to a link used for long distance 15 communication of many multiple signals, such as TV signals.

The invention also includes RF transmitters and RF receivers, described partly herein and partly in U.S. Patent No. 5,010,399,

that are connected to the telephone wiring of the local 20 networks and a local network interface device disposed between the local network wiring and the extended twisted pair wiring that leads to the transceiver/switch. These elements cooperate to provide the following results:

1) The transceiver/switch can select any one of the 25 signals provided by the high-capacity communication link and transmit it along the extended wire pair leading to any one of the local networks. At least one video signal can be sent to every local network at one time.

2) Normal telephone communication on all local 30 networks and between the local networks and the public network (trunk) is preserved. All pre-existing computer communication capabilities are also preserved.

3) A signal transmitted from the point of convergence will be received by the local network interface 35 and retransmitted onto the local network, making it

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available for reception by an RF receiver connected at any point on the local network. (In some embodiments, a local network interface is not included and signals transmitted at the point of convergence transmits directly onto the 5 local network for reception by a video receiver connected thereto.)

4) Any RF transmitter connected to a local network can transmit a signal to the transceiver/switch by transmitting that signal onto the local network. A signal 10 sent in this manner is received by the local network interface and retransmitted onto the extended twisted pair wire. (In some embodiments, a local network interface is not included and a signal applied to a local network by an RF transmitter is transmitted directly to the 15 transceiver/switch without interception and retransmission.) At least one video signal from each local network can be transmitted in this direction at the same time.

5) Any RF video receiver on a local network can 20 detect control signals from infrared transmitters (e.g., hand-held remote control devices typically used to control the operation of televisions, VCRs, etc.) and transmit them to the transceiver/switch, allowing the user to control program selection at the transceiver/switch from the 25 location of, e.g., any television connected to the local network through an RF receiver.

6) In addition to selecting any one of the signals provided by the high-capacity communication link for transmission along the extended wire pair leading to any 30 one of the local networks, the transceiver/switch can also select any of the video signals received from one local network for transmission to any other local network.

Other features and advantages of the invention will become apparent from the following detailed description, 35 and from the claims.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 1A show a signal splitter according to the invention that is useful with the communications systems described herein and, e.g., also in the 5 communications systems described in U.S. Patent No. 5,010,399.

Figure 2 illustrates certain properties of transmission of RF signals.

Figure 3 is a block diagram of an automatic gain 10 control (AGC) technique according to the invention.

Figure 4A is a block diagram of a transmitter/receiver pair according to one embodiment of the invention for communicating high-fidelity audio signals over active telephone wiring using FM techniques.

15 Figure 4B shows a component of the receiver of Fig. 4A in more detail.

Figure 5 is a block diagram of a transmitter/receiver pair according to another embodiment of the invention for communicating high-data rate digital 20 signals over active telephone wiring.

Figure 6 is a block diagram of a transmitter/receiver pair according to still another embodiment of the invention that uses digital techniques to communicate high-fidelity audio signals over active 25 telephone wiring.

Figure 7 is a block diagram of a pair of transceivers according to yet another embodiment of the invention for communicating video, hi-fi, and control signals over active telephone lines.

30 Figure 8 shows a portion of the coupling network used in the transceiver pair of Figure 7.

Figure 9 shows another portion of a coupling network used in the transceiver pair of Figure 7 that provides directional multiplexing.

35 Figure 10 is not used in this application.

- 35 -

Figure 11 is a block diagram that shows an interface between an active, internal residential telephone network and a public telephone network according to this invention, and several video transmitters and video receivers 5 connected to the internal telephone network.

Figure 12 shows an RF/video processor within the interface of Fig. 11 in more detail.

Figure 13 is a block diagram of a video receiver used in the system of Fig. 11 (and is identical to Figure 10 2 of U.S. Patent No. 5,010,399.)

Figure 14A shows how the RF spectrum below 140 Mhz may be allocated for transmission of video signals across the internal telephone network of Fig. 11.

Figure 14B illustrates an alternate allocation of a 15 portion of the RF spectrum of Fig. 14A.

Figures 15A-15C depict three embodiments of an RF converter in the video receiver of Fig. 13.

Figure 16 shows a control signal processor in the RF/video processor of Fig. 12 in more detail.

20 Figure 16a shows a component of the control signal processor of Fig. 16 in more detail.

Figure 17 shows a low-frequency processor in the interface of Fig. 11 in more detail.

Figure 18 shows an embodiment of the master 25 controller in the interface of Fig. 11 in more detail.

Figure 19 shows an alternative embodiment of a portion of the RF/video processor of Fig. 12.

Figure 20 is not used in this application.

Figure 21a is a block diagram showing the placement 30 of the transceiver/switch and local network interfaces in a system of telephone lines leading to multiple local networks according to one aspect of the invention.

Figure 21b is a block diagram showing the placement of the transceiver/switch of Fig. 21a between a PBX 35 ("private branch exchange") and the system of telephone

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lines leading to different rooms in an office building according to another aspect of the invention.

Figure 22 is a functional block diagram of the transceiver/switch of Figs. 21a and 21b.

5 Figures 23a-23c show different spectral distributions of video signals that are useful in understanding the invention.

Figure 24 is a block diagram of a processor in the transceiver/switch of Fig. 22.

10 Figure 24a shows additional details of a component of the processor of Fig. 24 that serves as an interface to the high capacity communication line.

Figure 25a shows another component of the processor of Fig. 24 that performs the distribution of signals to the 15 various local networks.

Figure 25b shows an alternative embodiment of the component of Fig. 25a that allows transmission of signals from one local network to a different local network.

Figure 25c shows another alternative embodiment of 20 the component shown in Fig. 25a.

Figure 26a shows additional details of still another component of the processor of Fig. 24 that performs the reception and disposition of signals sent from the various local networks.

25 Figure 26b shows an alternative embodiment of the component of Fig. 26a.

Figure 27 is a block diagram of a control signal processor in the transceiver/switch of Fig. 22 for processing the signals sent from the local networks to 30 control signal selection and other processing at the point of convergence.

Figure 28 is a table that summarizes the signals transmitted across the extended pairs in one of the examples used in the disclosure.

35 Figures 29a and 29b are block diagrams of

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embodiments of a signal separator in the transceiver/switch of Fig. 22, showing the electronics that route signals onto multiple extended pairs, route signals received from each extended pair, and process the telephone signals on the 5 extended pairs.

Figure 30 illustrates one embodiment of a local network interface of Fig. 21a.

Figures 31a-31c show additional details of various embodiments of components of the local network interface of 10 Figure 30 that process the non-telephone signals transmitting between the local networks and the transceiver/switch.

Figure 32 shows one of the RF processors that performs part of the function of the local network 15 interface of Fig. 30.

Figures 33a and 33b show additional details of the components of the local network interface of Fig. 30 that processes the telephone signals transmitting between the local networks and the transceiver/switch.

20 Figure 34 shows additional details of a wiring closet booster that includes several local network interfaces for boosting the levels of signals transmitting in both directions between the transceiver/switch and several of the local networks.

25 Figure 35 is a block diagram of a digital video receiver useful with the systems of Figs. 21a and 21b.

Figure 36 shows another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

30 **Part I - RF Broadcast System Utilizing Internal Telephone Lines**

The devices described herein, and those described in U.S. Patent No. 5,010,399, feed RF signals onto active telephone links (i.e., telephone wiring that is in use for transmission of ordinary voiceband signals) and recover 35 signals from the telephone wiring. The devices will also function correctly when used over inactive telephone links.

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Communication of video and infrared control signals in this manner was first described in U.S Patent No. 5,010,399. This document describes methods by which hi-fi audio and digital signals are communicated across active telephone 5 wiring as well.

When signals are transmitted over a telephone network, such as the internal telephone wiring of a residence, the signals spread to all parts of the network, and are thus available for recovery by any device that is 10 connected to the telephone wiring. As such, these devices use the wiring as a broadcast medium. They use RF frequencies, and function like wireless communication devices, except that telephone wiring, rather than the airwaves, is the medium.

15 The devices of this invention are designed to work on any network of telephone wiring in which an uninterrupted two wire conductive path (e.g., the red-green pair in a four conductor cable typically used to carry telephone voice signals) exists between any two points on 20 the network. The telephone wiring need not be "point-to-point" (i.e., splits and other junctions in the telephone wiring may exist between the two points) and loops are allowed. The internal network of telephone wires of nearly 25 all residences fit this description. The only common exceptions are residences where all jacks are directly connected to a central electronic switch/processor, sometimes referred to as a KSU or key-service unit. U.S. Patent No. 5,010,399 (in connection with Fig. 5) describes an adapter that provides an RF bypass around such a switch, 30 allowing transmission of video and control signals to all points of the telephone wiring. The same adapter can be used to allow other RF signals, including the signals described herein, to bypass the switch and broadcast across the telephone network. Such an adapter can also be used to 35 repair breaks in the conductive paths of other types of telephone wiring networks.

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U.S. Patent No. 5,010,399 describes a pair of transceivers which exchanges video and infrared signals over the active telephone wiring. The first transceiver transmits video signals to and receives infrared control signals from the second transceiver, and, of course, the second transceiver does the opposite. The first transceiver is referred to therein as the "video source transceiver" because it connected to a video source (such as a VCR). The second transceiver is called the 10 "television transceiver" because it ordinarily is connected to a television.

In this document, devices that transmit video signals over an active telephone network are referred to as "video transmitters," even though they may send or receive 15 signals of other types (such as purely audio signals, digital signals, etc.). Devices that receive video signals from active telephone wiring are denoted as "video receivers". Devices that both transmit video signals to and receive video signals from a telephone network are 20 referred to as "video transceivers"

Increasing the No. of Channels and the
Distance Over Which RF Signals
Can Transmit on Telephone Wiring

Using the techniques disclosed in U.S. Patent No. 25 5,010,399, a full cable band spanning sixty video channels can be fed to a one foot length of telephone wiring and transmitted with high quality without violating any FCC regulations. As the distance between transmitter and receiver increases, however, factors come into play which 30 cause higher frequency signals to drop out. The same phenomenon occurs with RF signals of other types. Thus, transmission length and the total number of available channels are closely related quantities. In this section, several techniques are disclosed to extend the limits to 35 these quantities.

The following equation governs whether transmission of an RF signal across telephone wiring can succeed:

- 40 -

$$SL - TL - PA > SNR + IL \quad (\text{equation } \#1)$$

where,

SL = Source level (dBmV),

TL = Transmission loss (dB),

PA = Point attenuation (dB),

SNR = Signal to noise ratio (dB), and

IL = Interference level (dBmV).

That is, high-quality video signals will be received if source signal level, less transmission loss, less point attenuation, exceeds the minimum required SNR by the amount of the interference. Each of these components is now discussed in the context of transmission across telephone wiring.

1) Signal level (SL). Generally, the technology required to amplify a video signal to the levels of interest in the systems disclosed in this application is simple and inexpensive. The real limits to signal level are dictated by legal (e.g., FCC) restrictions on the signal energy radiated from the wire. In experiments described in U.S. Patent No. 5,010,399, NTSC signals with a picture carrier at 61.25 Mhz applied to four conductor telephone wiring at 40dBmV slightly exceeded U.S. FCC regulations. Radiation caused by a signal at a fixed energy level increases as the frequency of that signal increases.

2) Transmission loss (TL). This is the signal energy lost by transmission across the wiring. This quantity is linearly related to the length of the wiring and increases significantly as frequency increases. At 100 Mhz, for example, typical telephone wiring attenuates energy at approximately 15dB per 100 feet, while at 175 MHz, attenuation is approximately 30dB per 100 feet.

3) Point Attenuation (PA). This quantity refers to the signal energy lost at a single point on the conductive path. Examples are the attenuation of RF energy by telephones, by "open" telephone wall jacks (i.e., jacks which are not connected to a telephone), and the loss at splits in the wiring. The loss at a split is approximately 3.5 dB. The loss at an open jack is smaller (less than 3.5 dB) because most of the energy is reflected back onto the line. Telephones can have a much higher attenuation affect than either an open jack or a split.

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4) SNR. This is the minimum SNR required at the receiver input to generate a good picture and is largely a function of how the signal is encoded and how picture quality is measured.

5 5) Interference level (IL). This is the energy level of the interfering signals found on the wiring. Some examples are signals from citizens' band (CB) radios and amateur radio signals that might be picked up by the wiring acting like an antenna. (The ability of the wiring to act as an receiving antenna increases with frequency, as does the radiating ability of the wiring.) Another interference source is the non-linear effects of certain telephones on RF signals. This is described in the section that immediately follows. Still another source of interference is the energy that crosses over from a second RF signal at the same frequency on a second pair of telephone wires in the same wire bundle. (As is known, a typical residential telephone wire bundle or cable includes two pairs of wires: a red-green pair, which is normally used for the primary line in residential telephone hook-ups, and a black-yellow pair, typically unused unless the residence is equipped with a second telephone line. In structures other than residences, large bundles are used that consist of many pairs of telephone wires.) This phenomenon is known as crosstalk and increases with increasing frequency.

30 It is interesting to note that transmission loss, radiation, interference, and crosstalk all increase with frequency, making the use of lower frequencies to transmit video, audio, or digital signals over the telephone lines according to the invention much more attractive.

35 To summarize some of the transmission properties discussed above, it is seen that increasing SL, decreasing TL, decreasing PA, decreasing minimum SNR, and decreasing IL will allow an RF signal at a fixed energy level to transmit over longer distances on a given network of
40 wiring. Equivalently, given a fixed transmission path and a fixed signal energy, those changes to SL, TL, PA, IL, and minimum SNR allow video to transmit at higher frequencies.

45 In the following five sections, methods to improve transmission via changes in PA, minimum SNR, and IL are disclosed.

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Decreasing Attenuation by Connected Telephone Devices (Figs. 1, 1A)

Many telephone devices load down RF energy on the telephone line. This attenuation can occur in both the on-hook and off-hook conditions. As described in U.S. Patent No. 5,010,399, when connected to a telephone network across which RF signals are transmitted, telephone devices can drain RF signal energy, lowering the level of the RF signal at the receiver. Given the attenuation properties of a specific telephone device, the degree of reduction of the RF energy level at the receiver depends upon the location at which the telephone device is connected to the telephone network.

When applied by a source (e.g., the video source transceiver) to the telephone wiring using the techniques described in U.S. Patent No. 5,010,399, RF energy is transmitted between the source and receiver (e.g., the television transceiver) over one or more conductive paths, that is, one or more branches of the telephone wiring. The shortest path is usually dominant, i.e., more energy arrives at the receiver by traversing the shortest path than by traversing any other. This is because energy attenuation is directly related to path length. One situation where the shortest path does not dominate is when it includes many junctions (such as branches that connect to secondary jacks), or splits. In this case, a longer path may be the dominant path. Another exception is where many telephone devices connect to the shortest path, attenuating the energy level below that of another path.

According to theory, there is a rough inverse relationship between the amount of RF energy drained by a telephone device and the distance of that device from the dominant transmission path. As described in U.S. Patent No. 5,010,399, physically long branches will serve to reduce the attenuation effect of a connected telephone device. The attenuation introduced by telephone devices connected through relatively long branches will be limited

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by the 3.5 dB splitting loss that long branches impose at a junction. If, on the other hand, the telephone device is connected to the dominant path through a branch that is not long enough to impose significant attenuation (e.g. less than 1 dB), the effective reduction of energy from the path can approach the full dissipative effect of the telephone device.

As mentioned in U.S. Patent No. 5,010,399, if a telephone device is connected to the dominant path through a low-pass filter, it cannot significantly drain RF energy from that path. It is suggested therein that low pass filters be supplied with both the transmitter and receiver so that telephone devices sharing the same telephone jacks as the transmitter and receiver do not load down the video signals. Because they necessarily connect to the dominant path, these devices are considered to be the most likely to cause signal attenuation.

Referring to Figs. 1 and 1A, experiments conducted by the inventors have since indicated that in many residences, providing all telephones with low pass filters decreases attenuation sufficiently to significantly increase the number of channels over which transmission can succeed. Such a procedure is feasible because simple, inexpensive low-pass filters can be enclosed in a compact housing which serves as a splitter 161 and includes standard RJ-11 telephone connectors 166, 167, 168 for providing connections to the telephone network, the telephone devices, and the video transmitter or receiver.

Splitter 161 includes a network port 168 that includes a male RJ-11 plug which is simply inserted into an existing RJ-11 outlet of the telephone network (not shown), replacing the single outlet with two alternative outlets, both of which are female RJ-11 connectors. One of the alternative outlets is a phone port 166 to which a telephone plug is connected. Within splitter 161, phone

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port 166 is connected to network port 168 through a pair of low-pass filters 162a, 162b. Low pass filter 162a filters signals present on the red-green wire pair, and signals on the black-yellow pair are applied to filter 162b.

5 Devices that transmit and receive RF signals are connected to splitter 161 at RF port 167. These devices include, of course, the video transmitters and receivers described in U.S. Patent No. 5,010,399, as well as any of the transmitters and receivers described herein. The 10 black-yellow wire pair is directly connected between RF port 167 and network port 168. A high-pass filter 164, double-pole-double-throw switch 165, and terminator 163 are connected as shown to the red-green pair between RF port 167 and network port 168 for purposes described in detail 15 in the following section.

Low pass filters 162a, 162b also suppress the transients from telephone switch-hook signals. These transients can include significant energy at higher frequencies. To suppress substantially all transients, 20 however, an additional low-pass filter should be placed along the path that connects the telephone wiring of the residence to the public telephone network. In a typical residence, this means placing the low-pass filter at the point where the telephone company wire enters the 25 residence. This will suppress substantially all high frequency energy that originates at the public exchange.

Although it is unlikely that the public exchange will provide significant high frequency energy, this filter also serves the purpose of blocking the high frequency 30 energy transmitting on the residential wiring from creating a violation of governmental regulations by conducting onto the public telephone system. For example, Part 68 of the U.S. FCC regulations places severe limits on the amount of energy that can conduct onto the public networks below 6 35 Mhz.

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Reducing the Likelihood of Interference
from Multipath Transmissions (Figs. 1, 1A, 2)

U.S. Patent No. 5,010,399 describes a series of tests involving transmission of television video signals across wiring of an internal residential telephone network to a television for viewing. One purpose of the tests was to determine if a type of interference called "ghosting" or "multipath" would appear in the image displayed on the television screen.

10 Multipath interference is caused by reception of the video signal of similar energy levels from multiple transmission paths. The classic example of multipath interference with video is when a signal transmits from an antenna to a television via two different paths. The 15 dominant path is the one that extends directly from the antenna to the TV. The secondary path reflects off a nearby building before arriving at the television.

20 The possibility of multipath interference with signals transmitting over telephone networks is present because of the many paths that signals can follow between source and receiver. This interference, however, was not observed in any of the tests performed. A brief explanation of its absence was included in U.S. Patent No. 5,010,399. In the following paragraphs, the issue of 25 multipath interference is discussed in greater detail, and a technique to eliminate it in situations where it may occur is described.

As mentioned above, multipath interference can occur when a video signal is transmitted between the video signal 30 source and receiver over paths of different lengths. The signal whose energy at the receiver is highest has usually traversed the most direct path. If a reflected signal is received at a level comparable to the signal provided by the direct path, multipath interference is created in the 35 form of a duplicated image that is offset horizontally on the television screen vis-a-vis the first. An example of multipath interference in the case of transmission over

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airwaves is where a second path reflects off of a nearby building before reaching the receiver.

Referring to Fig. 2, reflections can also take place on a network of telephone wiring. The most common points of reflection are where the wiring splits, and where a branch of wiring terminates at an open jack. Both of these types of reflections are shown in Fig. 2, which illustrates a portion of a telephone wiring network that includes a video transmitter 195 that transmits a video signal across branches 195a, 195b of the wiring to a video receiver 196. Branch 195c joins branches 195a, 195b at split 199. If branch 195c is short relative to one quarter of the wavelength of the signal (e.g. less than 10 meters at 30 Mhz) and is not connected to any telephone devices, theory dictates that its effect on the signal transmitting to receiver 196 will be minimal. (If branch 195c is short and is terminated with a telephone device, attenuation occurs as described above.) If the length of branch 195c is comparable to or larger than a quarter of a wavelength, however, a portion of the video signal will be reflected, at split 199, back to transmitter 195 with a 5 dB loss; the remainder of the video signal will be divided between branch 195b (leading to receiver 196) and branch 195c (which connects to termination 197). The signal level on each path 195b, 195c will be 3.5 dB below the level of the video signal incident at split 199 from transmitter 195.

If termination 197 is simply an open telephone jack, theory dictates that termination 197 will induce a phase shift and a small energy loss in the video signal on branch 195c which will then be reflected back towards split 199. At split 199, part of the energy in the reflected signal will again be reflected, this time back to termination 197, with a 5dB loss, part will be transmitted to transmitter 195 with a 3.5 dB loss, and part will be transmitted towards receiver 196, also with a 3.5 dB loss. This last component, the energy transmitting towards receiver 196,

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will represent the reflection with the highest level. It will have twice suffered a 3.5 dB loss at split 199, a reflection loss (induced by termination 197), and also the extra attenuation of traversing branch 195c two times. The 5 original video signal from source 195, on the other hand, will have suffered only a single 3.5 dB loss at split 199.

The amount of offset between the video signal that reaches receiver 196 through reflections in branch 195c and the video signal that is applied to receiver 196 10 directly from source 195 (i.e. through branch 195a, split 199, and branch 195b) is related to the time delay between reception of the direct and the reflected signal. The following analysis of television dynamics reveals how much delay is necessary to create visible interference.

15 The horizontal sweep rate of an NTSC television is 15,750 scans, or lines per second. If there are 300 pixels of resolution per line, 2.1×10^{-7} seconds elapse for each pixel. At a transmission speed of 3×10^8 meters per second, this means that the reflected path must be 20 approximately 120 meters longer than the direct path to cause a two pixel offset. Transmission speed over telephone wiring will be somewhat less, perhaps around 2×10^8 meters per second, meaning that a direct-to-reflected path length differential of approximately 80 meters will cause a two 25 pixel offset.

For the reflected signal to cause interference, it must be delayed long enough to cause significant offset while retaining enough of its energy to have a visible effect on the television picture. If two pixels are 30 considered to be the minimum noticeable offset, then the above computations indicate that the delay caused by a 80 meter or 250 feet detour will cause a two pixel offset. This can be caused by a branch 125 feet long.

At 30 MHz, attenuation of telephone wiring is 35 approximately 7 dB per one hundred feet. At that rate, the reflected path will suffer a 17.5 dB loss over a 250 foot

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detour. As a result, if branch 195c is 125 feet, the energy of the reflected signal in Fig. 2 will be at least 21 dB (17.5 dB due to the detour plus 3.5 dB contributed by split 199) below the energy video signal that follows the 5 direct path of branches 195a, 195b. The reflection loss at termination 197 may make the reflected signal level slightly lower. Because interference suppressed as much as 40dB can still affect an AM (amplitude modulated) video signal, the reflected signal would cause multipath 10 interference if the transmitted signal is AM encoded.

Splits and connected telephone devices encountered along a detour, however, can prevent multipath interference from occurring. Because it is unusual to find a "clean" 125 foot branch with no splits or telephone devices, this 15 is an important property. The mechanism by which splits and connected telephone devices can prevent multipath interference is explained in the following paragraphs.

The routing and attenuation of reflected signal energy is very different if the dashed line labeled sub- 20 branch 198 represents a secondary branch connected to branch 195c, whose length is comparable to or larger than a quarter of a wavelength. In this event, the split 198' created by sub-branch 198 causes the reflected signal analyzed above to lose 3.5 dB while passing from split 199 25 to termination 197, and another 3.5 dB while returning from termination 197 after the reflection. Although the lost energy stays on the network in the form of reflected signals that will ultimately find their way back to receiver 196, these "secondary" reflections will have 30 different delays or offsets. This means that their energy will not add coherently and the combined effect of the various reflected signals will be dominated by the effect of the strongest reflected signal. Termination 197, moreover, may include a connected telephone device which 35 can further attenuate the reflected signal.

Because 125 foot branches with no significant

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secondary branches and no connected telephones are unusual, multipath interference is not likely at 30 MHz or above. At 10 MHz, however, the attenuation of telephone wiring is approximately 2.5 dB per 100 ft. The loss due to 5 attenuation in this case is only 6dB. This means the energy differential between reflected and direct signals is less at 10 MHz than at 30 MHz, making multipath effects more likely at the lower frequency.

To avoid multipath interference, the following 10 solution, embodied in splitter 161 (Figs. 1 and 1A), is disclosed. Reflections at the termination (i.e., a telephone jack) of a long branch are suppressed by altering the impedance of the termination to match that of the wiring at the frequencies of transmission. Video signals 15 incident at such a termination will not reflect but will behave as if the conductive path continues without end. Thus, video signals and other energy presenting at this termination will be removed from the wiring network.

In some circumstances, the removal of energy by 20 these terminations can have a detrimental effect. Consider, for example, the case where a main transmission path has 10 short stubs connected to it, each of which provides a port for connection of telephones. Terminating each of these in this manner would remove 3.5 dB of energy 25 at each stub, a total reduction of 35dB. Because the ports are connected via short stubs, furthermore, they are not likely to cause multipath problems. Thus, termination of the stubs would be unwise in this case. (Use of low-pass filters to prevent draining of high frequency energy by 30 connected telephones, however, is still very useful.)

In general, branches should be terminated only when multipath interference would otherwise result from a reflected signal. In the case of AM video, interference only occurs when a signal traverses a reflected path longer 35 than approximately 200 feet, and is received at a level within 40dB of the level of the strongest signal.

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Figs. 1 and 1A show a method of altering the termination of a telephone jack at frequencies above voiceband. Video signals (i.e., RF signals as produced by, e.g., any of the transmitters disclosed herein) incident at 5 network port 168 on the red-green wire pair are applied equally to (i.e., split between) low-pass filter 162a and high-pass filter 164. The RF signals pass through filter 164 to switch 165, shown in its normally closed position in Fig. 1. Switch 165 is actuated by arm 165a, the position 10 of which is a function of whether a RF receiver (such as any of the receivers described in U.S. Patent No. 5,010,399 application or elsewhere in this application) is connected to RF port 167 or, alternatively, whether RF port 167 is "open."

15 Arm 165a is pivotally mounted at RF port 167 and biased by spring 165b to maintain switch 165a in the normally closed position whenever RF port 168 is "open" (i.e., does not have a telephone plug 167a inserted therein). As a result, if RF port 167 is open, the RF 20 signals from high-pass filter 164 (which is, for example, a single capacitor inserted in series on the red or green wires) pass through switch 165 to terminator 163. Terminator 163 absorbs all of the RF energy transmitting from the network to port 167, allowing no reflection. This 25 can be achieved with a simple resistor (such as approximately 100 ohms) that matches the impedance of the telephone line and connects from the red to the green wires.

When telephone plug 167a is inserted into port 167 30 (as shown in Fig. 1A), plug 167a pivots arm 165a downward, compressing spring 167b and changing the position of switch 165 to couple the RF signals between high pass filter 164 to RF port 167, bypassing terminator 163.

Frequency Modulation to Decrease Minimum SNR
35 and Reduce Distortion

In the general procedure described in U.S. Patent No. 5,010,399, video signals are converted to RF bands

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before being fed to the telephone wiring. Some of the specific conversion techniques described include the modulation of a basebanded video signal to an AM channel tunable by ordinary televisions.

5 Amplitude modulation (AM) has the advantage of being relatively inexpensive and narrow in bandwidth. Its drawback is that a high SNR is required for good picture quality. For NTSC signals modulated with a one-sided bandwidth of 4 Mhz, an SNR of at least 40dB is required.
10 (The one-sided bandwidth is defined as being the distance from the picture carrier to one end of the band.)

15 Modulating video signals using frequency modulation (FM) can alleviate the problems of high SNR requirements because the FM reception process is generally more sensitive than AM reception. This advantage follows from the fact that the SNR at the output of an FM receiver is generally higher than the SNR at its input. In other words, the "signal-to-noise" in FM is higher than the "carrier-to-noise." (In AM, by contrast, the "signal-to-
20 noise" is equal to the "carrier-to-noise.")

25 The improvement in minimum SNR depends on the nature of the noise, the nature of the reception and demodulation process and, in particular, the bandwidth of the signal. All other factors being equal, an improvement in minimum SNR will always accompany an increase in FM bandwidth. One example of the relationship of bandwidth to the SNR improvement is the VFMS-2000 system, an FM video modulate/demodulate pair built by CATEL Corporation. This pair uses 14 Mhz of bandwidth and provides an SNR
30 improvement of approximately 10dB over AM communication.

35 FM video signals with bandwidths wider than 20 Mhz are used in communication with satellites, resulting in advantages in sensitivity greater than 10dB. As the modulation index and thus the bandwidth increases, however, higher frequencies are required, causing increased attenuation at the high end of the signal, possibly

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cancelling the extra advantages. Nevertheless, use of very wideband FM signals in transmission of video signals in the applications addressed herein holds the promise of significantly increasing transmission length.

5 The power of FM signals to reject interference increases when the interfering signal is a second FM signal confined within the same channel. The minimum energy advantage that a receiver requires to reject a weaker but otherwise equivalent signal in the same channel is known as
10 the "capture ratio", and is often significantly less than the minimum SNR necessary to avoid distortion by white noise. The exact capture ratio will depend on several factors, but the inventors estimate that the capture ratio of an FM NTSC video signal with a 15 Mhz bandwidth will
15 typically be less than 10dB, allowing it to ignore interfering FM signals whose levels are suppressed by at least 10dB.

Another advantage of frequency modulation is that it makes the signal less susceptible to spectral tilt.
20 Spectral tilt, which is described in U.S. Patent No. 5,010,399, occurs when the signal energy at one end of a signal spectrum is out of proportion to the energy at the opposite end. When the difference is large it can cause distortion of amplitude modulated (AM) signals because
25 information is carried in the amplitude variations of the signal. Frequency modulated signals, by contrast, are relatively immune to spectral tilt because their information is encoded in frequency variations.

Spectral tilt often occurs during transmission
30 because the attenuation (per unit length) of the medium increases at the high end of the spectrum. The problem increases as transmission length increases. Wideband AM signals, such as standard NTSC video signals, are especially susceptible because the difference in
35 transmission attenuation between the high and low ends of their spectrum is likely to be more pronounced. By

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contrast, narrowband (such as audio) AM signals rarely encounter this type of distortion.

In the case of standard amplitude modulated NTSC video signals, the information in the lower half of the frequency band of the signal is redundant and is ignored by receivers. Thus, the difference between the signal level at the picture carrier frequency and the signal level at the upper end of the band (which is 4 Mhz above the carrier) determines whether interference due to spectral tilt is likely to occur.

Compensation for spectral tilt can be implemented at the receive end of the transmission path by boosting the level of the higher frequencies by the amount of extra attenuation that they experienced during transmission. The extra attenuation can be estimated, and the compensation "fine tuned" in response to that estimate. This is called equalization, and requires additional processing which raises costs and adds complexity. Alternatively, the higher frequencies of the signal can be amplified commensurately with the extra attenuation expected during transmission. This is called pre-emphasis and increases cost for the same reasons. If adjustable pre-emphasis or equalization circuitry is provided, the amount of compensation can be "fine tuned" in response to the observed quality of transmission.

Inspection of the relationship between signal frequency and the attenuation of signals by telephone wiring reveals the frequency bands in which the difference in the rate of attenuation between the two ends of a 4 Mhz band is significant. The attenuation of signals transmitting on telephone wiring at 61.25 Mhz, for example, is approximately 11 dB per 100 feet. At 65.25 Mhz, the rate is approximately 11.66 dB per 100 feet. Thus, the low end of an NTSC video signal transmitting at VHF channel 3 (which spans between 60 and 66 Mhz) will gain a .66 dB advantage over the high end for every 100 feet of path

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length. Similar analysis shows that the differential across any 4 Mhz channel is approximately the same for 4 Mhz bands whose low end exceeds 5 Mhz. (E.g., attenuation at 20 Mhz is .66 dB less per 100 feet than attenuation at 5 24 Mhz.) This is not generally true for frequency bands whose low ends are below 5 Mhz. This means that spectral tilt is not an important factor when comparing two bands whose low ends are both above 5 Mhz.

When the ratio of the upper frequency limit to the 10 lower frequency limit of a transmission channel is very large, spectral tilt can cause interference to FM signals if two signals within the same frequency band (channel) transmit on neighboring twisted pairs in a bundle. This problem, and a proposed solution, is described below in the 15 section that addresses the transmission of signals on tightly bundled twisted pairs.

Another advantage of frequency modulation is that it eliminates another form of distortion related to the varying attenuation caused by connected telephones. That 20 type of distortion is described later on in this application.

One drawback of frequency modulation is that it complicates the design of the video receiver. Specifically, RF converter 19 in Fig. 2 of U.S. Patent No. 25 5,010,399 must convert the waveform of the video signal in addition to converting the signal to a different frequency band. This is because most televisions can only receive AM signals. One preferred method is to detect the FM signal, thereby providing a signal in the baseband frequency range. 30 The basebanded signal is then amplitude modulated to a tunable channel.

Transmission at Empty VHF and
UHF Channels to Reduce Interference

One method of reducing interference is to transmit 35 the video signals within bands that are allocated by the FCC for television transmission but are not being used in the local area. Because the bands allocated for video are

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always off-limits to other types of sources, this assures the absence of any broadcast interference. This assures that the IF component in governing equation #1, above, is always a minimum. This makes transmission at these 5 frequencies more reliable from the standpoint that there is no danger that the IF component will have a dramatic and sudden increase due to a nearby broadcast source.

For example, frequencies below 30 Mhz are susceptible to interference from a nearby amateur radio 10 (HAM) transmitter operating in the 10, 15, 20, and 30 meter bands. The probability of such interference is small because the broadcasting antenna must be very close. Where there is no tolerance for such interference, however, the unused television channels are more favorable than the 15 frequencies below 30 Mhz, despite the increased transmission path length.

In U.S. Patent No. 5,010,399, reference is made to the use of empty video channels below VHF channel 7. Channels at VHF 7 and above were not considered good 20 candidates because of the extra radiation that would accompany their higher frequencies. By using frequency modulation or by installing low-pass filters at each telephone (such as by using splitter 161 above), however, the length over which signals at higher frequencies can 25 transmit is significantly increased. Because only two low VHF channels, VHF 3 and VHF 6, are empty in, among others cities, Los Angeles, New York, Chicago, Detroit, and Boston, these high VHF empty channels can be important.

In AM transmission, the signal bandwidth and channel 30 separation match the standard NTSC 6 Mhz channel system, so an AM signal can fit into any unused VHF or UHF television channel. FM transmission, by contrast, loses much of its advantage in minimum SNR when its bandwidth is confined within a 6 Mhz channel. Thus, consecutive empty channels 35 must be used for FM. Unfortunately, many large cities do not have consecutive empty channels in the VHF band. In

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New York City, for example, only channels 3, 6, 8, 10, and 12 are unused.

Many consecutive unused channels exist, however, in the UHF band, allowing one to find enough bandwidth to 5 accommodate an FM signal. Although the wire attenuation is higher at UHF frequencies, and radiation from the wire is also higher, if the telephone attenuation is significantly reduced (e.g., by using low-pass filters at each telephone) and the low minimum SNR advantage of FM is exploited, 10 transmission at these channels over the internal residential telephone network may well be commercially feasible.

Eliminating Disturbance of RF Video Signals
Caused by Voiceband Energy (Fig. 3)

15 The inventors have determined that, in addition to the attenuative effects of some telephones connected near the dominant path, certain telephones would occasionally disturb the television picture when voiceband signals were present on the telephone line. The inventors did not 20 correlate this interference with any particular class or category of telephone device.

In approximately one third of the residences tested by the inventors, a disturbance in the displayed picture was observed when any ordinary voiceband signal such as a 25 typical telephone conversation, a dial tone, touch tone, or rotary dial signal, was present. The interference was also noticed when a ring signal was applied to the telephone. Generally, if a voiceband signal caused a disturbance, the ring signal did as well. Conversely, if voiceband signals 30 did not cause a disturbance, ringing signals also did not.

The inventors traced the problem to one or more of the telephone devices connected to the network. Some of these devices only caused their disturbance when off-hook, some only when on-hook, some in either condition. The 35 problems only occurred when these devices were connected close to the dominant path -- as the distance to the

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dominant path increased, the interference always lessened. (When a video signal with a 25 MHz carrier was transmitting, telephones ceased to cause a disturbance when removed 60 ft from the dominant path.) When a low-pass 5 filter was interposed between the telephone and the wiring as described above, the disturbance disappeared completely.

Evidence indicated that variations in attenuation of RF energy by such telephone devices closely tracks the variations in the time-varying voltage that represents the 10 voiceband signals. This varying attenuation causes a rapidly varying video signal level at the video receiver. If the telephone device that induces the varying attenuation is connected close to the dominant path and the variations are large, the interference will be significant. 15 As is seen from the discussion above, amplitude modulated signals are much more likely to be affected by this interference than frequency modulated signals.

One method of substantially eliminating this problem in a given residence is to install low-pass filters on 20 every telephone. This was suggested earlier to expand the number of transmission channels. It is certainly feasible when installation of a video transmission system is performed professionally. It may not be practical, however, to require an ordinary consumer to perform this 25 installation.

An alternative solution is to install an automatic gain control (AGC) circuit in the RF device that receives the video signal (e.g., the television transceiver shown in Fig. 2 of U.S. Patent No. 5,010,399). The AGC circuit 30 smooths out the variations in video signal level caused by offending telephones before presenting that signal to the television. A description of a circuit that can perform this function is given below.

Let the attenuation of the offending telephone be 35 represented by the following equation (#2):

$$C + Bi(t)$$

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where C represents the constant component of the attenuation and $B_i(t)$ represents the time varying portion of the attenuation. B is a constant and represents the magnitude of the variations, and $i(t)$ is zero mean, unit power and represents the variation with time.

Now let the video component of the television signal at the receiver when the telephone is disconnected be denoted by $Vv(t)$, where V is a constant and $v(t)$ has a peak of unity and zero mean. The received signal when the phone connects is thus:

$$[C + B_i(t)] Vv(t) \quad \text{equation (#3)}$$

or

$$CVv(t) + VB [i(t)v(t)] \quad \text{equation (#4)}$$

or

$$15 [1 + (B/C)i(t)] CVv(t) \quad \text{equation (#5)}$$

The first term in equation #4 represents the video signal and the second term represents the noise.

Note that the quantity $[C + B_i(t)]$ in equation #3 (and the mathematically identical quantity $[1 + (B/C)i(t)]C$ in equation #5) multiplies the pure video signal $Vv(t)$. Thus, this quantity represents what can be called "multiplicative noise." This quantity is time varying due to the process $i(t)$, described herein. This quantity is also known as the "envelope." By smoothing out this variation, i.e. by using an AGC (automatic gain control) circuit in the receiver to apply a time varying gain equal to the inverse of this quantity, the noise can be canceled and only the signal, $v(t)$, will remain.

Applying AGC techniques to AM video, unfortunately, presents an additional difficulty. The difficulty lies in the fact that amplitude variations due to interference are not easily distinguishable from variations that represent the modulated signal. The solution disclosed herein (and shown in Fig. 3) measures variations in the amplitude of the sound component of the video signal to estimate the behavior of the interfering signal. This is possible

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because the sound carrier is frequency modulated, meaning that variations in its amplitude do not represent signal information, only interference. This interference, furthermore, will be very similar to the signal interfering 5 with the video component. That is because the video and sound components are relatively close in frequency. (The picture carrier in a NTSC signal is separated from the sound carrier by only 4.5 MHz.) It follows that the interference measured in this manner can be used to 10 compensate for the corruption of the video component. This procedure is described below.

Let $Ss(t)$ represent the sound component of the television signals, where s is constant. Because this signal is frequency modulated, the quantity $s(t)$ is a 15 sinusoid with time varying frequency. If that sinusoid is assigned an amplitude of 1, S becomes the amplitude of the signal.

When $Ss(t)$ replaces $Vv(t)$ in equation 5, the resulting expression, $[1 + (B/C)i(t)]CSs(t)$, represents the 20 disturbed sound signal. Furthermore, $[1 + (B/C)i(t)]CS$ can be viewed as the time varying amplitude of the sinusoid $s(t)$, because $i(t)$ varies much more slowly (it varies at voiceband frequencies) than $s(t)$. Because the inverse of the quantity $k[1 + (B/C)i(t)]CS$ (where k is a 25 multiplicative constant) when multiplied by the video signal $[1 + (B/C)i(t)]CVv(t)$ leaves the pure video signal $(k/S)Vv(t)$, if $k[1 + (B/C)i(t)]CS$ can be estimated, the video interference can be canceled.

An estimate of the time varying amplitude of the 30 sound signal, $[1 + (B/C)i(t)]CS$, is computed by computing the RMS of that signal over an averaging time long enough to smooth out variations in $s(t)$, but short enough to preserve variations of $i(t)$. Thus, the lower bound of the averaging time will be the inverse of the highest frequency 35 of $v(t)$, i.e. a value in the microsecond range. An upper bound will be the inverse of the maximum frequency of the

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baseband signal $i(t)$. This value will be in the millisecond range because $i(t)$ is in the telephone voiceband. An estimate of $[1 + (B/C)i(t)]CS$ will be .707 times the computed RMS.

5 Fig. 3 shows a block diagram that illustrates the estimation process. This process can be employed in, e.g., television transceiver 15 of Fig. 2 in U.S. Patent No. 5,010,399. A television signal is split and fed to bandpass filter 300 and gain control 303. The filter
10 attenuates the video component, leaving only the sound component, which is fed to RMS circuitry 301. That component estimates the RMS of the sound signal over an averaging period that is set according to the above description. As described above, this represents the
15 multiplicative noise in the television signal. This time varying quantity is inverted by invertor 302, and the resulting signal is used to control the gain applied by gain control 303 to the television signal. Varying the gain in this manner removes the noise according to the
20 procedure described above.

Standard television gain control circuits monitor the energy of the video signal, and apply an amount of attenuation or gain necessary to keep the signal at a desired level. Thus, the gain control smooths out the
25 variations in the amplitude of the received signal.

Standard gain control circuits have a response time of seconds. The amplitude changes caused that invertor 302 instructs gain control 303 to implement, however, occur at the rate of the highest frequency of the voiceband signals,
30 i.e. 5 KHz. This requires gain control circuits to react at least this fast, i.e. .2 milliseconds, in order to track voiceband changes effectively. This reaction rate is higher than that of gain control circuits typically used for video signals, but not beyond the most rapid circuits
35 that can be built with inexpensive electronics.

As discussed above, frequency modulated video

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signals are more immune to interference and are less likely to be disturbed by the phenomenon described in this section. In the event that this interference does corrupt an FM video signal, however, the compensation process can 5 be simpler than the procedure disclosed above. This is because the amplitude of the FM video signals, like FM sound signals, is not varied with time by the modulation, meaning that the amplitude variations of the video component correspond to the interfering signal. Thus, an 10 AGC circuit treating an FM video signal can react to variations in the video amplitude directly, rather than the variations in the sound carrier, and conduct the smoothing operation in the ordinary manner.

15 Transmitting RF Signals over Two
Different Wire Pairs in the Same Bundle

As discussed above, normal internal telephone wiring includes four conductors. Voiceband signals typically use the red/green pair for the first telephone line, and use the yellow/black pair if a second line is connected. Some 20 wiring includes many pairs within the same bundle (i.e., enclosed within a single sheath).

Some of the energy of RF signals can cross over from one wire pair to an adjacent pair within the same bundle, especially on four conductor wire. As frequency increases, 25 this crosstalk effect becomes larger. This will cause interference and prevent the use of the same frequency to transmit different signals on separate pairs in the same bundle. The crosstalk effect thus limits the opportunities presented by extra conductors to the lower frequency 30 ranges. An example is a cable consisting of a bundle of telephone wire pairs, and whose properties are such that when energy is fed onto one pair at 20 Mhz, it can be received, through crossover, at the end of the cable on a neighboring pair at a level only 40 dB lower than the level 35 on the identical pair. Because AM NTSC signals have a minimum SNR requirement of at least 40dB, this means that different signals cannot be transmitted onto different

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pairs at frequencies above 20 Mhz.

If two signals at the same frequencies are fed onto different pairs at separate locations on a network, the interference will depend on the relative locations of the 5 transmitters and receivers as well as the crosstalk. A more interesting and important question is whether two signals fed onto different pairs at the same point on the internal telephone network will interfere. This type of interference is called "far end crosstalk."

Because they are at the same frequency, the energy level of these two signals will decrease at the same rate. Thus, the levels reaching their respective receivers or reaching the point where the pairs separate, will be nearly the same. Also, the amount of energy crossing from one 15 pair to the second will approximately equal the energy crossing in the reverse direction. Furthermore, if the crosstalk energy is higher than other noise energy at the receiver, the SNR seen by either receiver is the ratio of the energy of the signal of interest to the energy crossing 20 over from the neighboring pair. The ratio of signal to noise in this case is simply:

$$\text{SNR} = \text{SL1} - (\text{SL2} - \text{CR}) \text{ equation (#5)}$$

where SL1 is the source level of the signal of interest, SL2 is the source level of the signal on the other wire 25 pair, and CR is the loss suffered by SL2 in crossing over. Because $\text{SL1} = \text{SL2}$, the SNR is simply CR. If this is less than the minimum SNR for the signal, the crosstalk effects will not degrade the video signal displayed by the television. The quantity CR is called the "far end 30 crosstalk loss."

Because the minimum SNR of AM video signals is at least 40dB, even a small amount of crosstalk can cause noticeable interference in the television picture. Because FM video signals have a capture ratio of less than 10dB, 35 however, the possibility that the second pair can provide extra video channels is significantly higher when FM is used.

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A problem can occur, however, when the ratio of the upper to lower frequency limits of the transmission band is large, i.e., when the spectral tilt is large. The problem occurs during the instant of time when the carrier of the signal of interest is at a high frequency deviation while the carrier of the interfering signals is at a low deviation. Ordinarily, if the crosstalk loss is greater than the "capture ratio," interference will not occur. Because attenuation at the higher end of the band can be dramatically higher than that at the low end, however, the energy of the interfering signal can actually be greater than that of the signal of interest.

For example, assume two signals are frequency modulated between 10 Mhz and 60 Mhz, and are transmitted onto different twisted pairs within a bundle 500 feet long. Attenuation at 60 Mhz is approximately 10dB per 100 feet, while attenuation at 10 Mhz is approximately 3 dB per 100 feet. After a transmission distance of 500 feet, therefore, the interfering signal when it is at 10 Mhz will be 35dB higher than the signal of interest when it is at 60 Mhz. Thus, if the far end crosstalk loss is less than 35dB, the interfering signal will be at a higher level, and the SNR will be less than 1.

The solution proposed herein is to apply the equalization or pre-emphasis process described above to frequency modulated signals. In that way, the received signal levels will be equal across frequency, and the interfering signal will not have a relative advantage when it is at lower frequencies. In the specific example given, pre-emphasis would provide the signal energy that is at 60 Mhz at a level 35dB higher than the energy at 10 Mhz. In that way, the levels of both frequencies at the receive end would be similar.

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Transmission of High-Fidelity Audio Signals
Across Telephone Wiring (Figs. 4A-4B)

Because most of the energy generated by high-fidelity audio systems is concentrated in the voiceband, 5 signals from those systems will interfere with telephone communications when transmitted across telephone lines. The solution disclosed herein uses a concept similar to that described in U.S. Patent No. 5,010,399 for transmitting infrared signals across active telephone 10 wires. Signals transmitted using that technique are first converted to a higher frequency band, then amplified before transmission onto the wiring. The resulting signal is received at the end of a path, and used to recreate the original waveform at baseband.

15 The application of this method to high-fidelity audio signals is shown in Fig. 4A. Left and right stereo channels at pre-amplified levels are passed from a sound system 151 to hi-fi transmitter 150. Modulator 152a modulates the left channel at a first RF carrier frequency, 20 (e.g., 45 MHz) and the right channel is modulated at a different RF carrier frequency, (such as 50 Mhz) by modulator 152b. Different carrier frequencies are used so that the modulated signals do not interfere with each other when they are combined by coupler 153 onto the same 25 conductive path. Because well-respected consumer electronic standards establish consistency in the voltage of pre-amplified signals, design of modulators 152 can achieve an economy by relying upon input levels within a narrow amplitude range.

30 The carrier frequencies must be high enough to convert all of the signal energy above voiceband. It may also help to leave the signals within a band where less governmental restrictions apply. In the U.S., for example, the Federal Communications Commission does not allow any 35 energy below 270 KHz to be fed to the public telephone network. They do allow, however, levels of -30dbV above that frequency. The U.S. FCC places no limits at all on

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energy above 6 MHz in frequency.

The typical method for modulating audio signals is to use techniques such as AM, FM, or SSB (single sideband). Each of these methods, of course, includes a companion 5 demodulator which converts signals back to their original form. A modulator/demodulator pair that cooperate in this manner may be thought of as a simple radio station and radio receiver that use the telephone wiring as a transmission medium.

- 10 FM transmission is the preferred method because the fidelity of a signal transmitted using that technique is higher than if AM or SSB were used with equally expensive circuitry. Signals converted via frequency modulation also have the added benefit of greater immunity to interference.
- 15 The audio quality when using FM would be commensurate with standard FM stereo reception. It could even be improved by using higher quality modulation circuits, or by increasing the bandwidth beyond the FCC regulations which restrict the bandwidth of broadcast FM. (More bandwidth is available on
- 20 the telephone lines because the only frequencies that are occupied on that medium are voiceband frequencies. Also, the bandwidth of FM broadcast stations is approximately 150 KHz, meaning that there is plenty of spectral space available for these types of signals, even if their
- 25 bandwidth is more than doubled.)

Coupler 154 applies the modulated signals to amplifier 154, and the amplified signals are passed through bandpass filter 155 to coupling network 156. Filter 155 restricts passage of energy between amplifier 154 and 30 coupler 156 to the frequency bands occupied by the modulated hi-fi signals. This prevents extraneous signal output from amp 154 from exiting onto the active residential telephone network 160 and prevents amp 154 from loading down RF signals that may be coupled across network 35 160 at different frequencies.

Coupling network 156 is shown in Fig. 4A. It

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includes hi-pass filter 146, and balancing and impedance matching circuitry 175. RF signals passing to coupling network 156 from network 160 pass through hi-pass filter 146, which blocks low-frequency (e.g., voiceband) signals 5 on network 160 so that connection and operation of transmitter 150 does not disturb telephone communications. Filter 146 can be implemented by a single capacitor connected in series along either of the two wires. It is not needed if the telephone wiring is inactive. The RF 10 signals then pass onto network 160.

Balancing and impedance matching circuitry 175 matches the impedance of the telephone line, reducing the energy radiated by RF signals crossing that junction, and increasing the efficiency of transmission onto the wiring. 15 It also balances the voltage of signals transmitting in the opposite direction, (i.e. onto the telephone network.) This also reduces radiation of energy. Balancing and impedance matching circuitry are shown in Figs. 6 and 7 of U.S. Patent No. 5,010,399, for a coupling network that 20 served as a junction of three paths. Those skilled in the art can convert the wound-torroid described therein to achieve the balancing and impedance matching results for this case, which is a junction of two paths.

Transmitter 150 also includes low pass filter 158a 25 and port 159 to allow connection of telephone devices 145 to network 160 through transmitter 150. Filter 158a isolates telephone devices 145 from network 160 at high frequencies, preventing devices 145 from loading down the modulated signals transmitted by coupling network 156. 30 Filter 158a can also constitute a component separate from transmitter 150. For example, low pass filtering is used to connect other telephone devices 145 elsewhere on network 160 (only one such connection is shown). One convenient way of providing the low pass filtering is to connect each 35 telephone device 145 to network 160 with splitter 161 (Fig. 1); in this case, the internal filters 162a, 162b of

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spitter 161 provide the low pass filtering.

Once they are applied to internal telephone wiring 160, the modulated signals flow to all points of the network. The hi-fi receiver 170 is connected at any 5 location on network 160 to recover those signals. The recovered signals first pass through coupling network 171. The functional block diagram for coupling network 171 is the same as that for coupling network 156 (Fig. 4A). Signals are received through a high pass filter that 10 presents a high impedance to voiceband signals, preventing the connection of receiver 170 from disrupting telephone communications. (This filter is not needed if the wiring is not active.) The signals next encounter balancing and impedance matching circuitry (similar to that discussed 15 above) to match the impedance of the telephone wiring to the impedance internal to the circuitry of receiver 170. The balancing circuitry unbalances the signal so that it is expressed inside receiver 170 as a voltage relative to ground. The signals then pass through bandpass filter 172, 20 which filters energy outside of the band occupied by the signals of interest. Demodulate and separate circuitry 173 then demodulates each of two signals independently, using known techniques to recreate the two original left and right channel audio signals, which are fed out through 25 ports 174. Demodulate and separate circuitry 173 also adjusts the energy level and impedance of the demodulated signals so that they adhere to the "line out" standards established for audio equipment. Typically, an amplifier (not shown) will be connected to ports 174 to boost the 30 audio signals and drive loudspeakers (also not shown). Of course, such an amplifier can also be provided internally, within the same housing as receiver 170. If an amplifier is provided internally, one need only provide hi-fi receiver 170 and any ordinary pair of loudspeakers to 35 produce the sound signal from sound system 151 at a remote location.

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A block diagram of demodulate and separate circuitry 173 is shown in Fig. 4B. Signals fed from filter 172 are split, passing to both filter 146a and 146b. Filter 146a passes only the frequencies of the left channel signal (in 5 this example, 45 MHz), and filter 146b passes only frequencies occupied by the right channel signal (50 MHz). The left channel signal is then processed by FM demodulator 147a, gain control 148a, and impedance matcher 149a. The right channel is processed by identical components.

10 FM demodulators 147a, 147b demodulate FM encoded signals that occupy the frequencies used by the left and right channel signals, respectively. This demodulation function is well known. After demodulation, the levels of the left and right channel signals are adjusted by gain 15 controllers 148a, 148b to adhere to the well respected standards used for the "line in" and "line out" ports on common audio equipment. Finally, impedance matchers 149a, 149b match the impedance of the conductive paths to the 75 ohm impedance required by the "line out" standards.

20 Receiver 170 includes low-pass filter 158c and port 176 for connection of telephone equipment. Filter 158c provides the same function as filter 158a. Filter 170 can also be provided as a separate component.

Fortunately, experiments indicate that internal 25 telephone wiring media are not likely to impose multipath or other distortions as FM encoded audio signals cross network 160. In those experiments, described in U.S. Patent No. 5,010,399, sound signals were transmitted using frequency modulation with center frequencies of 29.75 Mhz 30 and at 65.75 MHz. Those frequencies were the sound carrier frequencies of the NTSC television signals that were transmitted across residential wiring networks.

The FM sound components of those signals were fed onto the wiring at levels of approximately 25dBmV, which 35 was 15dB below the level of the video components. They communicated across all residences without substantial

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distortion or degradation. (Degradation of the video, but not the audio component was noticed in approximately 5% of all residences.) The attenuation caused by connected telephones, splits in the wiring, and the wiring itself did 5 not reduce the SNR of the signals enough to affect the resultant sound quality. This is due to the fact that FM receivers can tolerate low SNRs at their inputs without displaying significant interference at their outputs.

Besides revealing that the attenuative influence of 10 the network does not reduce the levels of FM signals enough to cause audible degradation, none of the experiments described in U.S. Patent No. 5,010,399 demonstrated interference from "airborne" RF signals picked up by the wiring. This is partly due to the fact that internal 15 telephone wiring acts as a poor antenna at the relatively low frequencies at which the FM encoded signals are transmitted over network 160, and also because quality reception of FM encoded signals is possible at low SNR levels. Furthermore, because sound signals are relatively 20 narrow in bandwidth, it is easy to find bands that are sufficiently wide yet are not likely to be shared by interfering broadcast energy picked up by the wiring.

In some residences and most small offices, telephone networks consist of several dedicated paths that connect 25 directly to a central switch, sometimes called a PBX for private branch exchange, or KSU for Key Service Unit. The conductive paths across this network are usually broken by such a switch. Such a break poses a barrier to the communication of video signals, as is described in U.S. 30 Patent No. 5,010,399. The same problem will be encountered by audio signals transmitted using the techniques described herein.

Adapter 52 shown in Fig. 5 of U.S. Patent No. 5,010,399, when installed at such a network switch isolates 35 that switch from RF video signals while allowing those signals to flow freely from one path to another. An

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adapter designed on the same principles will do the same thing for RF audio signals. In the event that the dedicated paths in a PBX network are very long, the attenuation of the wiring can cause the SNR at the receiver 5 to fall below acceptable levels. As described in U.S. Patent No. 5,010,399, an amplifier can be added to the adapter to boost the signal level before the second leg of the transmission path is traversed.

An interesting variation on the system of Fig. 4a 10 is to encode the left and right hi-fi channels using the same modulation system that FM radio stations use to broadcast stereo signals. When this is done, an ordinary radio receiver can receive the signals by connecting its antenna terminals to the telephone wiring through a high-pass filter. Replacing demodulate and separate circuitry 15 173 in device 170 by an antenna connected to a FM stereo radio provides that result.

Transmission of Digital Signals
Across Telephone Networks (Fig. 5)

20 Transmission of high data rate digital data streams across internal telephone wiring can be accomplished with commercially available devices known to transmit across that medium using wideband signals and frequencies above voiceband. Some of these devices allow communication 25 across wiring that is conducting voice communication. These devices are sometimes used in offices as part of computer communication networks.

These communication systems always transmit signals from one point to another along a "point-to-point" wire 30 35 that includes no splits or other junctions. An open question is whether these devices can achieve transmission over telephone wiring that is not "point-to-point" but includes many randomly connected paths. This would allow digital devices to communicate in a broadcast fashion, where a signal fed onto the wiring by a digital source spreads across the entire network and is available to a receiver that is connected at any branch of the network.

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The method disclosed herein for transmission of digital signals is based on the same principles as those described above and in U.S. Patent No. 5,010,399 for video and hi-fi signals. Experiments described in U.S. Patent 5 No. 5,010,399 demonstrated that NTSC video signals can transmit across networks of residential telephone wiring without substantial distortion. Because very high data rate digital signals have a bandwidth similar to that of NTSC and can often be received with lower SNRs, those 10 experiments indicate that data signals can also transmit in this manner.

Referring to Fig. 5, digital transmitter 178 is disclosed to feed high data rate digital signals, such as the 19.2 Kbit/sec signals generated under the IEEE RS-232 15 standard, onto active internal telephone network 188. Following is a description of the steps in the transmission process:

20 1) Digital signals are derived from a digital source 180, such as a the serial port on an IBM compatible PC.

25 2) The digital signals are fed to signal conditioner 181 that transforms the high and low voltages on the various conductors or "pins" of the port into a single analog wave expressed as voltage variations. This waveform may be as simple as a bi-level signal. It embodies not only the basic signal, but also information required for coordination with the receiver. The output signal produced by conditioner 181 is in the form at which 30 the signal can be efficiently transmitted across telephone network 188.

35 Many techniques are known to perform this conversion, such as the Bell 212 standard, which uses "phase-shift-keying" to achieve 1200 band communication in common modems. Devices that transmit signals according to the Bell 212 standard can input data from the serial port of a PC, and feed an analog waveform at voiceband frequencies onto an active telephone line. Another example of 40 this type of conversion is a technique known as Manchester coding, which outputs bi-level waveforms.

3) After being expressed as a voltage variation, the signal may be shifted to a different

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frequency using known heterodyne techniques. This is accomplished by RF converter 182. If some of the energy of the signal output from conditioner 181 is within the voiceband or overlaps the band used by other signals, this process is required. Otherwise, the process is useful only to take advantage of the different properties of the wiring at the shifted frequency.

Some conditioning techniques convert digital signals to the form of square waves whose energy is concentrated at frequencies above voiceband. Examples are the transmitters of LAN (Local Area Networks) that adhere to the 10BaseT standard. If conditioner 181 outputs its signal in this manner, converter 182 will not be required.

4) The level of the signal is increased by amplifier 185, and the amplified signal is coupled through a bandpass filter 183, which blocks energy outside the band confining the signal (i.e., voiceband). The signal now occupies the frequency channel at which it will transmit across telephone wiring 188.

5) The signals are then fed through a coupling network 184 and on to the network wiring 188. Network 184 balances the signal and matches the impedance of the telephone line. Network 184 also includes a high-pass filter on the port connecting to the telephone wiring. That filter blocks voiceband energy, making connection and operation of transmitter 178 transparent to voiceband communication. The requirements of coupling network 184 are the same as the requirements of coupling network 156, shown in Fig. 4a.

6) Port 184a is provided for connection of telephone devices. This port connects to the wiring through low-pass filter 184b that prevents those devices from draining the RF energy.

Signals transmitted according to the above process will ordinarily transmit across the entire network 188, and will thus be available to any cooperating receiver 179 that connects to the wiring anywhere in the residence.

Digital receiver 179 is also shown in Fig. 4. Following are the steps in the receiver process:

1) Receiver 179 connects to network wiring 188 to derive signals transmitting across that medium.

2) The signals are fed through coupling network 189, which performs the same functions as coupling network 171. The signals first pass

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through the high-pass filter of that network. That filter blocks voiceband energy. Next, coupling network 189 matches the impedance of the telephone line and unbalances the signal.

5 3) Signals emerging from the coupling network pass through band-pass filter 193, which attenuates energy outside the passband of the signal.

10 4) The signals are then applied to signal processor 190, which converts the signals to baseband frequency with an energy level inside the range expected by signal conditioner 191. This conversion may involve a shift in frequency or a demodulation, each of which can be accomplished using well known techniques, and are the inverse of the treatment provided by RF converter 182. Processor 190 may also perform an alteration of signal level using known AGC (automatic gain control) techniques. This is necessary because the level of the signal fed to the line by transmitter 178 may be very high, and if the transmission path is short, the signal received by receiver 179 will also be very high. An AGC can reduce the level of this signal to a range that is more easily managed by ordinary electronics. If transmitter 178 does not include RF converter 182, and the level of the signal received at network 189 will always fall within the range permitted by conditioner 191, processor 190 will not be required.

15 30 5) Signal conditioner 191 converts the voltage variations output by processor 190 into a digital data stream in a form expected by the connected digital terminal device 192. When the output of processor 190 is a square wave, digital devices may be able to read this output directly. In this case, conditioner 191 is not needed.

20 25 35 6) Port 189a is provided for connection of telephone devices. This port connects to the wiring through low-pass filter 189b that prevents those devices from draining the RF energy.

40 Techniques are disclosed herein and in U.S. Patent No. 5,010,399 to increase the maximum path length of transmission of video signals. These techniques will also facilitate transmission of high data rate digital signals as described above. Following is a partial list:

45 1) providing each telephone port on the network with either a low pass filter (shown in Fig. 5 as LPF 188a), or splitter 161, which includes a low-pass filter.

2) using frequency modulation in converter 182

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to increase interference rejection;

3) choosing transmission channels that are less likely to be used nearby broadcast sources, thus reducing the chance of interference;

5 4) reducing transmission frequency to lower the attenuation caused by the wiring, to lessen the ability of the wiring to pick up interference, and to allow higher signal levels without violating airborne radiation regulations;

10 5) providing a low-pass filter, shown in Fig. 5 as filter 188b, along the path connecting the network to an external signal source, such as the public telephone system, in order to suppress the higher harmonics of ringing voltage and switch-hook transients originating at the external source.

15 Transmitter/receiver pair 178, 179 can also achieve two-way communication by transmitting data in the reverse direction, from receiver 179 to transmitter 178, over the same pair of telephone wires of network 188 (but over a 20 different frequency band) using the same techniques as those described above. Techniques for simultaneous transmission and reception of various signals through a single connection to the wiring are disclosed in a later section of this document (entitled "Simultaneous 25 Transmission of Multiple RF Signals Across Internal Telephone Wiring").

Transmitter/receiver pair 178, 179 can also use the same channel for alternating two-way transmission if they cooperate to ensure that only one device is actively 30 transmitting at any one time. Such systems of cooperation are used in well-known computer communication networks.

Because the digital transmission technique described above is independent of the type of information represented by the data streams, digitized video signals can transmit 35 across networks of telephone wiring using that method. Transmission of digital video using this technique is facilitated by advancements in the compression of digitized video signals. These have enabled an impressive reduction of the data rate of the signal bitstreams and, 40 consequentially, an impressive reduction of the bandwidth

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required to transmit the signal. Commercial quality video signals can now be represented by analog waveforms covering less than 2 Mhz of spectrum.

When transmitter 178 and receiver 179 transmit digital video using the techniques described above, the process is a specific embodiment of the more general technique disclosed in U.S. Patent No. 5,010,399. The functions performed by RF converter 3 of U.S. Patent No. 5,010,399 correspond to those performed by signal 10 conditioner 181 and RF converter 182, and those performed by RF converter 19 in transceiver 15 in U.S. Patent No. 5,010,399 correspond to the functions performed by signal processor 190 and signal conditioner 191. The amplifiers, bandpass filters, and coupling networks of the 15 corresponding devices also perform identical functions.

Transmission of Hi-Fidelity Audio Signals
Across Telephone Networks
Using Digital Techniques (Fig. 6)

A system for transmitting high-fidelity audio 20 signals based on FM techniques was described earlier in this document with reference to Figs. 4A-4B. Inexpensive electronic components that perform FM modulation, however, may not be precise enough to support the sound quality generated by audio components that operate on digital 25 principles. It is for this reason that, for example, music created directly from compact discs meets higher specifications than music received from FM broadcasting, even if the source of the broadcast music is a compact disc.

30 Digital transmission techniques provide an acceptable alternative. The proposed procedure (shown in Fig. 6 and discussed in detail below) begins by digitizing audio signals or starting with a digital audio source. These signals are transmitted using the techniques 35 described in the previous section. The analog signal is then reconstructed at the receive end. Digitizing and reconstructing can be accomplished by devices known to

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digitize sound signals and to transform them back with no significant loss in quality.

The digital transmission concept is shown in Fig. 6. The system includes hi-fi transmitter 200 that accepts 5 analog pre-amplified left and right channels from an analog stereo system (not shown) or digital audio channels from a digital stereo source 204. Transmitter 200 processes these signals and transmits them onto the active telephone wiring 220. Hi-fi receiver 210 recovers these signals from the 10 telephone wires at a second location on network 220 and converts them to their original, pre-amplified form so that the audio signals can be used as input to a speaker/amplifier system.

Transmitter 200 accepts the left and right channel 15 analog stereo signals at ports 201 and 202 and transmits them to digitize and compress circuitry 203a and 203b, respectively. Because well-known consumer electronic standards establish consistency in the voltage of pre-amplified signals, design of circuitry 203a and 203b can 20 achieve an economy by relying upon input levels within a narrow amplitude range.

According to mathematical principles, the digitization rate must be at least twice as high as the highest signal frequency in order to capture all of the 25 information. Thus, 50,000 samples per second will capture all information up to 25,000 Hz, a frequency slightly higher than the highest frequency used in standard digital sound systems, and above the range of human hearing.

The left and right channel analog signals are 30 digitized and compressed by converter and compression circuitry 203a, 203b, respectively. The preferred method is to use the standard digitization and compression procedure used to create common compact discs. The advantage of that method is that inexpensive integrated 35 circuits are available to accomplish digitization and compression according to that standard. Use of a CD coding

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system for circuitry 203a, 203b also ensures that the transmission process will maintain CD sound quality within the system.

The CD system uses 16 bits to represent each sample 5 of the signal, and uses compression techniques to reduce this quantity to 12 bits. Because 50,000 samples encoded at 12 bits each results in 600,000 bits, digitize and compress circuitry 203a, 203b will each produce a datastream of 600,000 bits per second.

10 Some hi-fi components, especially CD players, output their signals as digital datastreams as well as in analog form. When connecting to these players, circuitry 203 is not necessary. Port 204a is provided to receive these digital outputs and to feed them directly to RF encoder 15 205, the next step in the processing stream.

To transmit this digital information across telephone wiring at a very low error rate, known circuits common to computer "local area networks" can be used. The two datastreams are passed to this type of circuit, RF 20 encoder 205, which represents each of them as variations of voltage across two wires at a frequency above voiceband. The input to RF encoder 205, by contrast, is digital and is typically expressed as time varying bi-level voltages on several conductors. An example of an RF encoder that 25 inputs digital signals and outputs an RF signal between 3 MHz and 15 Mhz, i.e. above the voiceband, are any of the transmitters that adhere to the IEEE 10BaseT standard. (As described in the background section of this document, that standard governs the Local Area Networks (LANs) that 30 transmit 10M bits/sec of data over twisted pair wires that are dedicated for point-to-point communication.)

The signal generated by encoder 205 passes through coupling network 206 onto telephone network 220. Network 206 feeds that signal to telephone wiring 220 through a hi- 35 pass filter that prevents disturbance with telephone communications. (This hi-pass filter is not necessary if

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the wiring is inactive.) Coupling network 206 also matches the impedance of the telephone line and balances the signal across the two leads of the telephone wiring. This reduces radiation and increases the efficiency of transmission onto 5 the wiring. The function of coupling network 206 is identical to that of network 156, shown in Fig. 4A.

Transmitter 200 also includes a low-pass filter 216 and a port 215 for connection of telephone equipment to network 220. Filter 216 prevents the telephone equipment 10 from loading down the RF signals fed onto telephone wiring 220. To prevent telephone devices connected to network 220 from loading down RF signals from transmitter 200, low pass filters are provided for each telephone. These are shown 15 in Fig. 6 by filter 216a and splitter 161, which includes a low-pass filter. Splitter 161 also provides other benefits when transmitting RF signals across telephone networks. These were described earlier in this document.

The frequency and level of the signal that is fed to telephone wiring 220 is determined by RF encoder 205. 20 As in the case of FM modulated audio signals described earlier, these values should be such that the SNR at the receiving locations is sufficient to provide high quality stereo. In this case, that requirement is roughly equivalent to the requirement of error-free reception of 25 the digital data stream. The signal level must also be low enough to keep RF radiation from the wiring below the legal limits established for the frequencies of the signal, and below the limits on the amount of energy that can be fed to the public telephone network. Experiments performed by the 30 inventors in transmitting video signals across all but the largest residences, indicate that the same combinations of frequency and signal levels, which are within legal limits, will transmit hi-quality stereo over the active telephone lines within all but the largest residences in the U.S. 35 This is because the SNR required at the input to an AM video receiver is much higher than the SNR required at the

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input to high data rate digital receivers such as those that adhere to the 10BaseT standard described earlier.

The RF signal is transmitted onto, e.g., a red-green wire pair of telephone network 220 and propagates over the 5 telephone link. At the receiving end, the RF signal is recovered by coupling network 207. The functions performed by network 207 are identical to those performed by network 171 of Fig. 4A. Coupling network 207 feeds the RF signal to RF decoder 208, the companion to RF encoder 205. 10 Decoder 208 recreates the left and right digital datastreams from the recovered signal using known means. Thus the outputs of decoder 208 will typically be time varying bi-level voltages adhering to one of the common standards for digital communications.

15 The remaining step in the receiving process is to recreate the analog left and right channel audio signals from the digital datastreams. This is the inverse of the digitize-and-compress process performed by circuitry 203, which follows the standard of common CD players and is 20 described above. It is performed by decompress and D/A (digital to analog) integrated circuitry 211a, 211b. The resultant left channel audio signal in analog form is applied to output port 212, and the right channel audio signal is coupled to output port 213. Because the 25 preferred decompress and digital-to-analog circuitry is common to virtually all CD common players, circuitry 211a, 211b can be provided inexpensively.

To recreate the sound, an amplifier (not shown) can accept the recreated signals from ports 212 and 213 and 30 drive speakers (also not shown), which serve as the "receivers" for the audio system. An amplifier can also be provided internal to receiver 210. In this case one need only provide receiver 210 and any ordinary pair of loudspeakers to produce the sound signal from a sound 35 system at a remote location.

Receiver 210 also includes a low-pass filter 209 and

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a port 214 for connection of telephone equipment to the network. Filter 209 prevents the telephone equipment from loading down the RF signals fed onto the wiring. Likewise, telephone equipment connected elsewhere on network 220 5 should use low pass filters, or even more preferably, splitter 161 (Fig. 1).

Because of the limitations, described earlier, of transmitting hi-fi signals across AC power lines, or broadcasting hi-fi signals using radio waves, 10 transmitter/receiver pair 200, 210 constitutes a significant advance in consumer electronics. The advance is even more pronounced when the ability to transmit infrared control signals in the reverse direction is included. Technology to achieve simultaneous transmission 15 of these signals is disclosed in the next section with regard to Fig. 7.

Simultaneous Transmission of Multiple RF Signals Across Internal Telephone Wiring (Figs. 7-9)

U.S. Patent No. 5,010,399, together with the 20 previous sections in this application, describe various techniques for transmitting audio, video, digital, and control signals from infrared transmitters over active networks of internal telephone wiring using radio frequencies. U.S. Patent No. 5,010,399 also describes a .25 pair of transceivers that cooperate to transmit video from one transceiver to the second, and control signals from the second transceiver to the first. In this section, these results are extended to disclose a transceiver that can connect to an the active wiring of a residence to transmit 30 several RF signals of varying types while receiving several others at the same time.

The general design will be described using a pair of transceivers that cooperate to transmit hi-fi, video, and control signals from infrared transmitters across 35 telephone wiring. The processing and signal flow within this pair is shown in Fig. 7.

A video source 251 and a hi-fi source 252 are shown

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connected to the transceiver on the left, herein referred to as the video/hi-fi transmitter 250. A television receiver 275 and a speaker/amplifier 276, are shown connected to the transceiver on the right, herein referred 5 to as the video/hi-fi receiver 280.

A wireless infrared source 277, which is normally a hand-held infrared transmitter, sends infrared control signals through the air to video/hi-fi receiver 280. An infrared receiver 253, which corresponds to the infrared 10 pickups on video source 251 and hi-fi source 252, receives the infrared control signal after transmission over active telephone wiring and reconstruction by transmitter 250 (as described in detail in U.S. Patent No. 5,010,399 and as also described below). Telephone equipment 263 and 266 is 15 shown at both ends because it is likely to be connected at any telephone jack. Likewise, telephone equipment 278 is connected through low pass filter 279 (which may be one of the low pass filters of splitter 161 of Fig. 1) at any location on telephone network 264.

20 Communication of signals across telephone wiring 264 by transmitter 250 and receiver 280 functions as follows. The signals from sources 251, 252 are first processed by respective processors 254, 255 to convert them to the form in which the signals will be efficiently transmitted over 25 the network 264. (The details of this processing is described later on.) These signals are then passed through respective bandpass filters 257, 258 and are combined by a coupling network 260 for transmission over a single pair of wires (e.g., the red-green pair) of network 264. It will 30 be appreciated that coupling network 260 receives signals from all sources connected to transmitter 250, as well as incoming signals recovered from telephone network 264. The combined, outgoing signals emerge from coupling network 260 and pass through a high-pass filter 261 onto network 264. 35 Filter 261 presents a high impedance to telephone signals from network 264 and makes the connection of transmitter

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250 transparent to voiceband activity on network 264.

At receiver 280, signals are recovered from the line through a high-pass filter 265 and are applied to coupling network 267. The functions of filter 265 are similar to 5 those of filter 261. Coupling network 267 has an output port for each of the connected receivers, e.g., television 275, and amplifier 276, which are the final destinations of the video and audio signals, respectively. The output ports of coupling network 267 are applied to bandpass 10 filters 269, 270 and then to processors 272, 273 where the video and audio signals are converted to a form compatible with their associated receiver 275, 276, respectively. The details of this processing are described later on.

The general procedure just described is embodied in 15 transceivers 1 and 15 of U.S. Patent No. 5,010,399, which cooperate to transmit video and infrared signals. This procedure is also used to communicate hi-fi audio signals and digital signals by the three transmitter/receiver pairs 150/170, 178/179, and 200/210 described above.

20 Communication of signals also takes place in the opposite direction. Specifically, infrared control signals from source 277 are detected by process 274, converted to electrical signals at an RF frequency, and transmitted through filter 271 and coupling network 267. These signals 25 then transmit through filter 265 and across network 264. At video/hi-fi transmitter 250, the control signals are received through filter 261 and transmit through coupling network 260 and filter 259, being received by signal process 256. That component converts the control signals 30 to infrared form, and broadcasts them to receiver 253.

Although some of the functions of the electronic components in Fig. 7 are described above and in U.S. Patent No. 5,010,399, the description is repeated below for easy reference.

35 Coupling network 260 provides junctions for the signals converging at transmitter 250. Coupling network

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267 provides an analogous function in receiver 280. In addition to supplying a simple junction of four paths, each network 260 and 267 also matches the impedances of the various paths, and balances signal energy across the two 5 leads of the transmission line (i.e., the red-green wire pair of network 264 over which the signals are transmitted). Both the impedance matching and signal balancing reduce radiation, while impedance matching makes transfer of energy across the junction that each coupling 10 network 260, 267 introduces more efficient.

One embodiment of coupling network 260 is shown in Fig. 8. The principle element of this network is a transformer wound on a torroid core 260'. There are four isolated windings corresponding to the ports leading to 15 filters 257, 258, 259, and 261. The winding arrangement method shown for the phone line port (in which two lines of the port are connected to a center tap of the winding and interconnected ends of the coil) serves to maximize the balance of signals transmitting on the path leading from 20 that port.

There are different number of windings on the torroid core for the four different ports. (The number of windings shown are only for purposes of illustration.) The turns ratios determine, approximately, the impedance 25 matching between the telephone port and the other three ports. Different ratios will be needed if the telephone line port has a different impedance at the frequencies used for transmission of the various signals.

Coupling networks 260 and 267 can also be designed, 30 using known devices (such as RF splitters and filters) to provide the function of directional multiplexing. This can be used to separate or isolate the three different signals that converge at their ports. These functions and the reason they are required are described in greater detail 35 below.

High-pass filter 261 (Fig. 7), which can be provided

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by a single capacitors connected in series along either of the wires of the conductive path, connects between network coupler 260 and the telephone network 264 to block transmission of signals below the highest frequency ordinarily used by telephone equipment. High-pass filter 265 performs an analogous function in receiver 280. This renders connection and operation of the transceivers completely transparent to any low-frequency communications. In U.S. Patent No. 5,010,399, these high-pass filters are included as part of the coupling networks.

Ports 262a, 268a are supplied by transmitter 250 and receiver 280 for connection of telephone equipment. These ports are connected to telephone network 264 through low-pass filters 262 and 268, respectively. Filters 262, 268 prevent telephone equipment 263, 266 from "loading down" any of the signals used by this communication system (i.e., the video, audio, and control signals exchanged by transmitter 250 and receiver 280 over network 264).

As discussed above, signal processing is nearly always required to transform the signals before they are fed to telephone network 264. According to the transmission techniques described above and in U.S. Patent No. 5,010,399, signal processor 254 may modulate, frequency shift, or amplify the video signal it receives as input. Signal processor 255 may perform the same or different processes on the hi-fi audio received from source 252. Finally, processor 274 (in receiver 280) transduces infrared signals from IR transmitter 277 to electrical signals and modulates and amplifies the electrical signal for transmission over network 264.

Similarly, processing of the recovered signals is sometimes needed to convert them to a form expected by the target receiver 275, 276, 253. According to the communication techniques described above and in U.S. Patent No. 5,010,399, processor 272 may demodulate or frequency convert the video signals for television receiver 275 and

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it may also perform automatic gain control. Signal processor 273 demodulates and performs AGC on the audio signals destined for speaker/amplifier 276. Finally, signal processor 256 (in transmitter 250) also demodulates 5 its input, amplify the resulting signal, and convert it to infrared light for use by infrared receiver 253.

The details of the processes that apply to hi-fi signals and some of those that apply to video signals are described earlier in this document. Other details that 10 apply to video signals and details that apply to control signals from infrared transmitters are described in U.S. Patent No. 5,010,399. It will be apparent to those skilled in the art that providing for communication of digital signals within this system can use the signal processing 15 described in connection with transmit/receive pair 178/179 described earlier in this disclosure.

Filters 257, 258, 259, 269, 270, and 271 provide frequency separation and isolation between the video, audio, and control signals, and between this group of 20 signals and the telephone signals present on active telephone network 264. If, for example, a video signal transmits within the band spanning from 24 MHz to 30 Mhz, the passband of filters 257 and 269 will cover those bands. If audio signals transmit within the band from 45 to 50 25 Mhz, the passband of filters 258 and 270 covers those frequencies. Finally, if the control signals transmit within a narrow band centered at 10.7 MHz, filters 271 and 259 will be passband filters centered at that frequency. The specifics of these functions are described in the 30 following paragraphs. An explanation of how directional multiplexing in the coupling networks can also provide some of these functions is presented after that.

Each of the filters 257, 258, 259, 269, 270, and 271 are applied across one of the two-wire paths leading from 35 a coupling network 260, 267 towards one of the sources or receivers. These filters will attenuate signals at

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frequencies outside the band of the signal intended to cross that path. Although this filtering is not always necessary, it can never be functionally harmful, and it can be important for several reasons.

5 First of all, filtering can prevent the component opposite the coupling network from loading down a foreign signal, draining energy away from its intended receiver. One example is filter 257, which, by blocking energy at the frequency of the control signals (from IR transmitter 277),
10 substantially prevents loading processor 254 from loading down the energy of those signals. If not for filter 257, processor 254 could attenuate or reduce the SNR of the control signal incident at processor 256 below adequate levels. Filter 258 functions in a similar way to
15 substantially prevent loading of the control signals by processor 255, and filter 271 substantially prevents loading of the video signal or the hi-fi signal by processor 274.

Filtering can also prevent receivers or processing
20 components from reacting to signals other than the signals of interest. If filter 259, for example, has a narrow passband centered at the frequency of the control signals, it will prevent the video signal and the hi-fi signal from reaching signal processor 256. Because the video and hi-fi
25 signals are being transmitted onto telephone network by transmitter 250, they are at a much higher energy level than the recovered control signals for infrared receiver 253, and would ordinarily disrupt processor 256. Similarly, filter 270 may be necessary to prevent the
30 control signals from disrupting the operation of processor 273.

As described in U.S. Patent No. 5,010,399, processor 272 can include a video channel conversion possibly followed by AGC, or automatic gain control. Neither of
35 these processes, however, are likely to be affected by the control signal energy. Furthermore, control signal energy

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reaching the TV is not likely to be a problem because televisions suppress energy at frequencies other than the ones to which they are tuned. The attenuation of the control signals from IR transmitter 277 provided by filter 5 269, therefore, may not be important.

Finally, filtering can prevent energy generated by a source 251, 252, 277 at out-of-band frequencies from reaching the rest of the system. Effectively, this "cleans up" the respective source signals. An example is filter 10 271 which, by having a passband cutoff slightly above the fundamental frequency of the control signals produced by processor 274 can block harmonics of such signals. This will be important if the harmonics include energy at the same frequencies over which video signals (destined for 15 receiver 275) or the audio signals (for use by speaker/amplifier 276) are transmitted. For example, if processor 274 generates a control signal centered at 10.7 Mhz, it is likely to have significant harmonic energy at 21.4 Mhz. If filter 271 is a low pass filter with a cutoff 20 of 15 Mhz, it will pass the fundamental of the control signal, but not the 21.4 Mhz harmonic. This will prevent that energy from interfering with reception, by process 272, of video signals covering that frequency.

Processor 254 includes a video modulator and 25 processor 255 includes a hi-fi modulator. Thus, they are likely to include filters that suppress out-of-band frequencies internally.

As discussed above, coupling networks 260 and 267 can provide directional multiplexing to achieve some of the 30 isolation described above. Specifically, coupling network 260 can be designed to isolate the three paths leading to the video, audio, and control processors. This will substantially prevent the video and audio signals from being applied to, and possibly interfering with the 35 operation of, control signal processor 256.

Fig. 9 shows a design that will accomplish this

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isolation, as embodied in network coupler 260. The signals from video processor 254 and the signals from hi-fi processor 255 are applied to the inputs of splitter 281. Splitter 281 couples both input signals to splitter 282 through line 281a, but does not permit either input signal to cross over between the video and audio paths. That is, splitter 281 provides a high degree of isolation between paths 254a and 255a. Another port of splitter 282 is coupled through line 256a to control signal processor 256. The third port of splitter 282 is connected through line 282a, through balancing and impedance matching circuitry 282b to high-pass filter 261. Splitter 282 allows the combined video and audio signals to flow through to filter 261 and onto telephone network 264, but prevents crossover of those signals to line 256a that carries the control signals. Control signals transmitting from filter 261 pass through splitter 282, with half of the energy transmitting towards control signal processor 256, and the other half transmitting towards the other processors 254, 255. Thus, the control signals suffer approximately a 3db loss due to the split. Processors 254 and 255, however, are substantially prevented from loading down the control signal energy.

Coupling network 267 can provide similar directional multiplexing. Specifically, coupling network 267 can isolate the three paths leading between the telephone network 264 and the video, audio, and control processors 272-274 in receiver 280. This can prevent the control signal from being applied to signal processors 272, 273, and can prevent processor 274 from loading down the video or audio signals.

The embodiment of coupling networks that perform the balancing and impedance matching described above is described in detail in U.S. Patent No. 5,010,399 for the case of RF video signals and RF modulated control signals. Techniques to extend those networks to include other RF

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signals is a procedure that will be apparent to those skilled in this technical field. Techniques to include the directional multiplexing in these networks are also well known.

5 Although the transmitter 250 and receiver 280 transmit video and audio in one direction and control signals in the reverse direction, these devices demonstrate the principles of transmission and reception of multiple RF signals by a single device that connects to active
10 telephone wiring. Using these techniques, those skilled in the art can design devices that transmit and receive any number of video, audio, and other sources (such as digital sources). The limits on the number of signals will be dictated by governmental limits on electrical radiation and
15 the increasing

attenuation of the wiring as higher frequencies are used.

Part II - Cable Television Distribution and Communication System Utilizing Internal Telephone Lines

General Overview (Fig. 11)

20 Referring to Fig. 11, an interface 300 between public telephone network 301 (i.e., telephone lines located outside of a residence) and a network 302 of telephone wires disposed internally within the residence includes a low-frequency signal processor 311 and an RF/Video processor 312 that communicate signals across residential active telephone wiring network 302 under the control of master controller 316. Processors 311, 312 and master controller 316 are included (together with filters 313 and 314) within the same housing, indicated by interface box
25 300, and connect to network 302 at the same point. This allows easy communication between processors 311, 312, and master controller 316.

Video transmitters 304a-304c and video receivers 303a-303d are connected to residential telephone network
35 302 via individual telephone jacks (also called nodes) and transmit and receive video signals and infrared control signals as described in U.S. Patent No. 5,010,399 and Part

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I of this disclosure. In the example shown, video receivers 303a-303c are connected between network 302 and televisions 305a-305c, respectively, and video receiver 303d is connected between network 302 and VCR 307. Video transmitters 304a-304c are connected between telephone wiring 302 and camera 306, video game 308, and VCR 307, respectively. Low-pass filters 309a-309c are disposed between respective telephone devices 310a-310c and the jacks leading to network 302 to block high frequency signals, such as switchhook transients, that may be generated by the telephone devices. Filters 309a-309c also prevent telephones 310a-310c from loading down the energy of video signals transmitting across the wiring. This possibility exists because video signals and telephone signals are all transmitted over the same pair of wires, such as the red-green pair, of network 302. This type of communication system is described in detail in U.S. Patent No. 5,010,399 and Part I of this disclosure.

High pass filter 313 and low pass filter 314 separate the signals transmitting between network 302 and interface 300. High pass filter 313 ensures that only video signals (i.e., signals transmitted from video transmitters 304a-304c to RF/video processor 312 or those transmitted by RF/video processor 312 to video receivers 303a-303d) pass between network 302 and RF/video processor 312. Low-pass filter 314 allows only low-frequency signals (e.g., the telephone signals) to pass between low frequency processor 311 and network 302. RF/video processor 312 also receives incoming signals from coaxial cable 315a that connects to port 315 on interface 300 (cable 315a receives cable TV signals from outside the residence), and exports video signals through port 321 on interface 300 for purposes described below.

RF/video processor 312 transmits video and control signals onto network 302 and simultaneously recovers both types of signals from network 302. The video signals it

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receives are those transmitted by video transmitters 304a-304c. The video signals RF/video processor 312 transmits may be those provided by cable 315a that connects through port 315, or they may be those it receives from 5 network 302 and retransmits onto network 302 at different frequencies, all as described below.

The ability of processor 312 to retransmit received video signals allows video transmitters 304a-304c and video receivers 303a-303d to communicate video information by 10 relaying such signals through RF/video processor 312. That method has some important advantages, described later on, over direct transmission of signals from the video transmitters (e.g., transmitter 304a) to the video receivers (such as receiver 303b). Communication by direct 15 transmission (e.g., directly between transmitter 304a and receiver 303b) is, of course, also possible.

In addition to the electronic functions of the various components, coordination of: 1) the channels used for transmission by RF/video processor 312; 2) the channels 20 chosen by transmitters 304a-304c; and 3) the specific path, either direct or retransmitted, have a large affect on the viewing options and conveniences available at televisions 305a-305c. Several systems of coordinating these functions are described herein, each of which has particular 25 advantages.

Low frequency processor 311 connects to network 302 via low pass filter 314. This prevents processor 311 from loading down high frequency (e.g., video) signals on network 302. As discussed below, processor 311 detects 30 touch tone (DTMF) signals from any telephone 310a-310c on internal network 302, detects DTMF signals transmitting from network 302, senses incoming telephone calls (i.e., the ringing signal) from public network 301, and passes telephone signals between telephone networks 301, 302.

35 Master controller 316 achieves two-way communication with processor 311 and RF/video processor 312 via

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respective sets of communication links 311' and 312'. (Links 311', 312' each include multiple individual wires.) In addition to the data applied over these links (described below), links 311', 312' allow controller 316 to direct the 5 operation of processors 311, 312. Standard digital communication links are adequate for links 311' and 312'.

Master controller 316 also communicates, via link 311', with a modem 317 that is disposed within low frequency processor 311 and connected to public network 10 301. Effectively, this allows master controller 316 to transmit and receive digital signals over public telephone network 301.

Master controller 316 operates under the control of the user. The user can exercise this control by 15 communicating with controller 316 through keypad/display 320 (which is, e.g., mounted on the exterior of a housing that contains interface 300), which connects to controller 316 via link 316'. Communication port 319 also provides communication with controller 316. It conducts 20 communication over link 319' using standard techniques such as the IEEE RS-232 standard. This allows many different digital devices to connect to controller 316. As described in detail below (see Fig. 18), master controller 316 includes a processor and a digital memory to allow the user 25 to program controller 316 with a set of commands using standard digital programming techniques.

The user can also communicate with and exercise control of master controller 316 by applying DTMF signals onto network 302 from any telephone 310a-310c. The DTMF 30 signals pass over network 302 in the ordinary manner, and are received by processor 311. (As is known, DTMF signals have frequencies within the telephone voice band, such as 4000 Hz or below, and thus are passed by low pass filter 314.) Processor 311 detects the DTMF signals and converts 35 them to digital signals using any suitable technique. The digitized signals are relayed to processor 316 via

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communication link 311'. The operation of controller 316 in response is discussed in more detail below.

The user can also communicate with and exercise control of master controller 316 via control signals from 5 infrared (IR) transmitters (such as an ordinary, hand-held IR remote control unit 307') that are transmitted to RF/video processor 312 via telephone wiring 302. As discussed in U.S. Patent No. 5,010,399 and Part I of this disclosure, the IR signals are detected by a video receiver 10 (such as video receiver 303a), converted to electrical signals at frequencies that differ from both the video signals and the telephone signals on network 302, and transmitted onto the network 302. The control signals are detected by RF/video processor 312 and converted to digital 15 signals (also using techniques that are described in U.S. Patent No. 5,010,399 and Part I of this disclosure), and are transferred to master controller 316. The details of how master controller 316 responds to the control signals are described below.

20 Master controller 316 communicates with the user by providing textual and other graphics overlaid on the video signals distributed through the residence and viewed on televisions 305a-305c. This is done with graphics processors 329a-329e (Fig. 12) in a manner discussed in 25 more detail below. Master controller 316 also directs RF/video processor 312 to transmit electrical versions of the infrared control signals that control the infrared responsive devices in the residence. Examples of this capability are also described at greater length below.

30 RF/Video Processor 312 (Fig. 12)

RF/video processor 312 improves the video transmission system by recovering video signals transmitted on network 302 by video transmitters 304a-304c, and retransmitting the recovered video signals to receivers 35 303a-303d. RF/video processor 312 also selectively transmits externally provided signals available at port 315

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over network 302 together with (or in place of) the retransmitted video signals. As discussed, the signals applied to port 315 typically are incoming cable TV signals provided by a local cable TV company, but of course any 5 video signals fed to port 315 can be used.

The signals transmitted by processor 312 onto network 302 are recovered by video receivers 303a-303d, converted to ordinary television signals, and passed to connected televisions 305a-305c, and VCR 307, respectively.

10 To implement these functions, RF/video processor 312 works together with controller 316 to perform the following:

15 1) Simultaneous reception, via telephone wiring 302, of video signals from video transmitters 304a-304c and of control signals from IR control devices (e.g., remote control 307') via video receivers 303a-303d.

20 2) Conversion of externally provided video signals (e.g., cable TV signals applied to port 315) to the waveform, frequency, and energy level at which they will be efficiently transmitted across telephone wiring 302.

25 3) Conversion of video signals received from transmitters 304a-304c on network 302 in one frequency band to a different frequency band and a higher energy level (and possibly to a different form of modulation) for retransmission to video receivers 303a-303d on network 302.

30 4) Transmission of stored commands that correspond to electrical versions of the infrared signals transmitted by control devices (such as remote control 307') used to control infrared responsive video sources connected to network 302. These signals are transmitted in electrical form across network 302 to video transmitters 304a-304c which, in turn, recreate the infrared patterns that control the devices and broadcast the IR signals for receipt and response by VCR 307 and other infrared responsive devices.

35 40

Step 1 is thoroughly discussed in U.S. Patent No. 5,010,399. U.S. Patent No. 5,010,399 and Part I of this disclosure also describe the relationship between signal energy, frequency band, and waveform and the ability to

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transmit across the telephone wiring. Described in this section are several techniques for assigning frequency bands (i.e. channels) to the various signals that are sent over network 302, and details of several devices that 5 implement these techniques.

As shown in Fig. 11, RF/video processor 312 connects to network 302 via the red/green wire pair of the telephone line, which is the preferred pair for transmission of RF frequencies. (The black/yellow pair, of course, could be 10 used instead of the red-green pair). Wire pair 313a, which connects to the red-green wire, leads through high-pass filter 313, which blocks only low-frequency (i.e., telephone) signals, allowing RF/video processor 312 to receive all RF signals fed onto network 302 at other 15 locations.

RF/video processor 312 can convert a video signal that it recovers from a video transmitter 304a-304c to a different frequency band (and possibly also to a different form of modulation, such as AM or FM) and retransmit the 20 converted video signal over network 302. The retransmitted signals are then recovered from network 302 by video receivers 303a-303d. There are several possible advantages to this. First of all, video signals that are transmitted in frequency modulated (FM) format by video transmitters 25 304a-304c can be converted to AM (amplitude modulation) by RF/video processor 312 before retransmission. This confines all conversion circuitry to a single device, which should be somewhat less expensive than providing conversion circuitry in each of receivers 303a-303d. (Conversion is 30 required because typical televisions can only tune AM.) Secondly, if all signals transmitted by video transmitters 304a-304c are retransmitted by RF/video processor 312, all signals reaching any video receiver 303a-303d originate from the same point. This can also simplify the design of 35 the receivers 303a-303d, as will be shown later. Finally, retransmission places all video signals under the control

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of a common processor -- RF/video processor 312. This allows a single device to perform additional processing, such as inserting graphical overlays, on any signal, as described later on.

5 Referring also to Fig. 12, details of RF/video processor 312 are now described. Fig. 12 also shows residential telephone network 302 (as a single block) and master controller 316. All other major components shown are part of RF/video processor 312.

10 Coupler 325 provides the interface to network 302 via high pass filter 313. Coupler 325 includes five ports, and allows free passage of signals in all directions. It also matches the impedance of each port to that of the telephone line, and balances the signals transmitting onto 15 network 302 across the two conductors of that line. (A similar coupling network that includes four ports is shown in Fig. 8 of Part I of this disclosure.) Extension of that network to provide the function of this network is believed to be a straightforward procedure to those of ordinary 20 skill in this technical field.)

Because coupler 325 allows free passage of signals in all directions, filtering at its ports determines which signals are transmitted along the various paths leading from coupler 325. This is possible because the RF signals 25 generated by transmitters 304a-304c ("video in") and the RF signals transmitted by subprocessor 337 ("video out") are all in different frequency bands; in addition, the "video in" signals and the "video out" signals are at frequencies that are outside of the frequency band that contains the 30 control signals broadcast by receivers 303a-303d ("control in") and the control signals generated by processor 330 ("control out"). Thus, bandpass filter 335 passes the "video in" signals to demodulators 326a, 326b while rejecting the other three signals just described. 35 Similarly, bandpass filters 334, 336 route the "control in" and "control out" signals to and from control signal

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processor 330. Finally, bandpass filter 333 passes only the "video out" signals intended for transmission onto network 302 from subprocessor 337.

The signal path leading from filter 335 to 5 demodulators 326a, 326b splits so that demodulators 326a, 326b each receives all of the RF signals recovered from network 302. Cable TV signals provided at port 315 are split three ways, and are applied to demodulators 326c-326e. Amplifiers (not shown) may be provided before 10 splitting to compensate for the splitting loss and ensure that all demodulators 326a-326e receive input signals at sufficiently high SNRs.

Demodulators 326a-326e comprise the first stage of selection and conversion subprocessor 337, the primary 15 functions which are to: 1) select several video signals from among those received from network 302 and those provided by cable 315a; 2) descramble, if necessary (with demodulators 326a-326e), each of the selected signals; and 3) convert the selected signals to the waveform, frequency 20 band, and energy level at which they will be efficiently transmitted across network 302 to video receivers 303a-303d.

In other words, two communication lines apply input signals to subprocessor 337: the red/green twisted pair 25 313a of the telephone line and the incoming coaxial cable 315a that connects at port 315. Each of these lines provides multiple video signals at different channels. Subprocessor 337 selects some of these signals, combines them onto a single path at different channels, and provides 30 the combined signals as output (called "video out" in Fig. 12).

Subprocessor 337 includes two additional functions. One of these functions is to alter video signals by overlaying graphics on selected signals passing through its 35 circuitry. Graphics processors 329a-329e are used for this purpose. The other secondary function is to provide video

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signals to port 321 (which serves as an auxiliary output for video signals, enabling the signals to be transmitted, e.g., to remote locations outside of the residence).

There are many ways that subprocessor 337 can be 5 implemented to fulfill these functions. Indeed, the closed circuit TV industry provides a large variety of video processing devices that couple video signals, separate video signals, modulate and demodulate signals, and shift signals in frequency. What is shown herein is a method 10 that is preferred in this application, as well as several alternatives.

Demodulators 326a, 326b are frequency demodulators (details are shown only for demodulator 326a) and include a tunable local oscillator and a frequency shifter for 15 converting a selected RF signal to an intermediate frequency (IF) band for demodulation. Master controller 316 selects the RF signal to be demodulated by independently tuning the local oscillators of demodulators 326a, 326b via link 326'. (Link 326' includes a conductor 20 for each demodulator 326a-326e.) The IF signal is then frequency demodulated to obtain a signal at baseband, which in turn is descrambled (if necessary) to produce the output of the demodulator 326a, 326b.

A local oscillator and a mixer are provided in each 25 AM demodulator 326c-326e (details of demodulator 326e are illustrated) to convert selected cable TV signals applied via port 315 to intermediate frequencies. After the IF signal is filtered, it is envelope detected and descrambled (if necessary) and applied to video switch 328. Master 30 controller 316 selects the cable TV signal (e.g., the channel) that demodulators 326c-326e are to process by independently tuning their local oscillators via link 326'.

Although five demodulators are shown, more or fewer can be used.

35 Thus, it may be appreciated that controller 316 independently instructs each of demodulators 326a-326e via

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link 326' to select and demodulate any of the signals provided by cable 315a or network 302. Each of the five resulting basebanded audio/video signals is then passed to video switch 328. That is, each demodulator 326a-326e 5 selects the signal from one or the other of its two inputs, as determined by controller 316 and communicated over link 326'. A standard demodulation procedure is then applied to this signal, converting the energy within the frequency band corresponding to the "channel" selected for 10 conversion. This "channel" is determined by controller 316 and communicated to the demodulator. The demodulation procedure converts the energy in that channel to a basebanded video signal.

As shown in Fig. 12, switch 328 includes five input 15 ports and six output ports. Each input port receives a video signal and its accompanying audio signal from a demodulator 326a-326e. Likewise, the six output paths of switch 328 each provides the video and audio signals of a television channel. Five of the output ports are connected 20 to graphical processors 329a-329e, respectively; the sixth is coupled to port 321. Video switch 328 switches signals from among the five input ports to any of the six output ports. The assignments of input to output are determined in controller 316 and communicated to switch 328 via 25 communication link 328'. No output port of switch 328 can be provided with more than one signal.

As shown in Fig. 12, switch 328 can provide any of the basebanded signals supplied by demodulators 326a-326e to port 321 for provision to an external device not shown 30 in the drawing. (Under the most general implementation, any of the signals passed to graphical processors 329a-329e, or to modulators 327a-327e, or output by modulators 327a-327e can also be routed to port 321.) An example of specific circuitry to provide these options is not shown.

35 Port 321 is a coaxial port that is provided on the housing of interface 300 because the selection,

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descrambling, and conversion operations performed by processor 312 can be useful for purposes other than transmitting signals across network 302. Specifically, port 321 is useful for provision of video signals to nearby 5 devices at tunable frequencies. For example, one can connect a VCR to port 321 to record signals recovered from network 302. Because this connection can be made via coaxial cable, ordinary video channels can be used, and the VCR can tune the signal directly (VIA its audio/video 10 inputs).

Each of graphical processors 329a-329e can either process its input and pass it a corresponding one of modulators 327a-327e to which it is connected, or it can bypass the processing, sending the video portion of the 15 input signal to such modulator 327a-327e directly. The decision to bypass is determined by controller 316 and communicated to the processor via communication link 329'. The bypass can be implemented by a simple switch (not shown). More or fewer than five graphical processors 329a- 20 329e can be used.

The processing conducted by each of graphical processors 329a-329e alters the signal passing through the processors 329a-329e between switch 328 and one of modulators 327. Two particular alterations or processes 25 are envisioned. One is the overlaying of text on the picture. (An example of this is a VCR or a cable converter that displays the identity of the selected channel by superimposing the channel number on the screen.) The second alteration is the control of the volume of the audio 30 signal. Both of these processes can be applied to basebanded television signals using well known techniques.

Each of the modulators 327a-327e converts the basebanded signal that is applied to it (as is shown, the baseband signal includes unmodulated video information from 35 0 to 4.2 MHz and an audio sub-carrier that is frequency modulated at 4.5 MHz) to the channel (i.e., frequency band)

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and waveform (e.g., AM) used for transmission over internal telephone network 302, as discussed below.

Each modulator 327a-327e (details of only modulator 327e are shown) is an amplitude modulator that includes a fixed-frequency local oscillator (which provides the video carrier frequency), a mixer, and a filter for passing only one sideband (such as the lower sideband) of the mixer output to coupler 331 as the output of modulator 327a-327e. The local oscillators of modulators 327a-327e are preset to different frequencies so that coupler 331 can combine the five outputs onto a single conductive path (such as the red-green pair of telephone wiring) without the signals interfering with each other. For example, the local oscillators of modulators 327a-327e can be set so that modulators 327a-327e respectively produce five AM signals in adjacent 6 MHz bands between 0 and 30 MHz (e.g., frequency range 340b of Fig. 14a). Although five modulators are shown, more or fewer can be used.

Thus, master controller 316 does not control the selection of the modulation frequencies employed by modulators 327a-327e. Of course, if such control is desired, controller 316 can select different modulation frequencies by embodying the local oscillators of modulators 327a-327e as tunable (i.e., "agile") devices, and linking them to controller 316--in much the same manner in which the local oscillators of demodulators 326a-326c are controlled.

The relationship between transmission quality and frequency band and type of modulation provided by modulators 327a-327e is described in U.S. Patent No. 5,010,399 and Part I of this disclosure. Any suitable modulation technique, such as frequency modulation, can be used in place of AM, if desired. The channels provided by modulators 327a-327e must not overlap each other or the frequencies used by any the signals fed onto network 302 by video transmitters 304a-304c ("video in") or the

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fréquences used by the control signals applied over network 302 to ("control in") or from ("control out") RF/video processor 312.

Coupler 331 collects all of the modulated signals produced by modulators 327a-327e onto a single conductive path 331a and feeds them to amplifier 332, which increases the energy level of the signals. This increase brings the signals to the energy levels required for transmission across the telephone wiring of the network 302. In general, the levels should be as high as possible without generating radio waves above the legal limits. The amplified signals pass through filter 333 to coupler 325. The filtering impedes amplifier 332 from loading down any of the RF signals on network 302.

Video receivers 303a-303d on network 302 receive the signals generated by modulators 327a-327e, process them, and feed them to the connected devices, i.e., to televisions 305a-305c and VCR 307. The processing performed by each receiver 303a-303d converts each signal to a form tunable by ordinary televisions. Video receivers 303a-303d also detect infrared light patterns representing control signals, convert these patterns to electronic signals (i.e., time-varying voltages), and transmit them onto telephone wiring 302. These functions are fully described in U.S. Patent No. 5,010,399 and Part I of this disclosure.

Video receivers 303a-303d are each embodiments of transceiver 15, shown in Fig. 2 of U.S. Patent No. 5,010,399. (Although component 15, like video receivers 303a-303d, transmits control signals and receives video, it is referred to as a transceiver in U.S. Patent No. 5,010,399, rather than a video receiver.) Several different specific embodiments of transceiver 15, described below, enable it to cooperate with the various systems, also described below, for switching video signals and for assigning frequency bands (i.e. channels) to the various

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video signals. These systems determine the tuning options of each of connected televisions 305a-305c, and VCR 307. These embodiments are described below.

5 Channel Selection when the Video Receivers Tune Only a Single Fixed Channel

Because of switch 328, any of the video signals produced by demodulators 326a-326e can be directed to any one of modulators 327a-327e, which will respond by applying a signal onto network 302 within a fixed channel (i.e., a 10 preset frequency band). This means that each video receiver 303a-303d need only convert signals in the single channel (i.e., frequency band) used by one of modulators 327a-327e to make all video signals from processor 312 available to the television connected to that receiver 15 303a-303d. This also means that master controller 316 determines which signals are fed to each of televisions 305a-305c (by controlling the selection and operation of demodulators 326a-326e and video switch 328).

When video receivers 303a-303d only receive signals 20 that are transmitted by RF/video processor 312 over a single fixed channel, the design of receivers 303a-303d is simplified. (Several alternative embodiments of receivers 303a-303d that take advantage of this simplification will be described shortly.) Also, channel selection and volume 25 control can be implemented totally within processor 312, so that no settings on the connected television need be disturbed. Because of these simplifications, this system of signal selection and switching is preferred. The functioning of such a system is illustrated by the 30 following example.

Video transmitter 304a (connected to camera 306) transmits its signal using FM encoding in a 12 MHz frequency band between 28 and 40 Mhz, while video transmitter 304c (associated with video game 308) transmits 35 its signal using FM at frequencies between 40 and 52 Mhz. Video transmitter 304b, connected to VCR 307, transmits its signal using FM between the frequencies of 52 and 64 Mhz.

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As seen from Fig. 12, each of these signals is applied to both demodulators 326a, 326b, while incoming cable signals (via cable 315a) in the same or different frequency bands are applied to modulators 326c-326e.

- 5 Now, let modulator 327a amplitude modulate its input signal, providing that signal within a 6 Mhz AM channel between 16 Mhz and 22 Mhz, and let the video receiver 303a connected to TV 305a be fixed to convert AM signals between those frequencies to either VHF channel 3 or 4. Further,
- 10 let modulator 327b amplitude modulate its input signal, providing that signal within the channel between 10 Mhz and 16 Mhz, and the video receiver 303b connected to TV 305b be fixed to convert AM signals between 10 and 16 Mhz to either VHF channel 3 or 4. Finally, let modulator 327c amplitude
- 15 modulate its input signal, providing that signal within the channel between 22 Mhz and 28 Mhz, and let video receiver 303d connected to VCR 307 be fixed to convert AM signals between 22 and 28 Mhz to either VHF channel 3 or 4.

Under this arrangement, switch 328 (as controlled
20 by controller 316) can independently supply televisions 305a-305b and VCR 307 with any of the signals on network 302 or supplied through cable port 315. For example, to direct the signal from video game 308 to TV 304b, demodulator 326a demodulates the 40-52 Mhz FM signal (from transmitter 304c), and controller 316 directs switch 328 to apply that signal to modulator 327b. As described above, modulator 327b will transmit the game signal using AM between 10 and 16 Mhz. As a result, video receiver 303b converts that signal and supplies it to TV 304 at VHF
25 channel 3 or 4.

Several designs are now discussed for video receivers 303a-303d that cooperate with the system for communication with RF/video processor 312 described immediately above. The requirements of that system are
30 that a video receiver:

- can connect to telephone network 302 without disturbing telephone communications,

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- can receive a video signal from telephone network 302 within a particular frequency band, and convert that signal to one that can be tuned by ordinary televisions,

5 - can detect infrared control signals, convert them to electrical signals at frequencies above voiceband, and transmit them onto telephone wiring 302.

All of these requirements are met by transceiver 15,
10 shown in Fig. 2 of U.S. Patent No. 5,010,399. Thus, video receivers 303a-303d are all embodiments of that device.

Video receiver 303a is shown in Fig. 13 of this application. Video signals on network 302 present to coupling network 342, which routes them to RF converter 15 345. That component converts the video signal from the frequency at which it is received to a signal that can be fed to the connected television 305a. IR sensitive diode 343 detects infrared signals (e.g., from hand held remote control device 307'), converts them to voltage variations or other electrical signals, and passes the electrical signals through coupling network 342 and onto network 302. All the elements shown in Fig. 13 are identical to those of transceiver 15 of U.S. Patent No. 5,010,399. The variations in receiver 303a disclosed in the following 25 paragraphs are each expressed as an alternative embodiment of RF converter 345.

One embodiment of RF converter 345 is shown in Fig. 15A. RF converter 345 includes a demodulator/modulator pair 346, 349. Incoming, modulated video signals from 30 coupling network 342 (Fig. 13) are applied to demodulator 346, which converts the modulated signals to baseband using well known procedures. The demodulated signal is passed to modulator 349, which converts the signal to a channel tunable by ordinary televisions (such as VHF channel 3 or 35 4).

As described in U.S. Patent No. 5,010,399, there is an advantage in allowing the user to choose to provide the received video signal at one of two adjacent low-VHF

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channels (e.g., VHF channel 3 or VHF channel 4). This allows the user to avoid interference of the output signal with local television broadcast sources. Modulation channel control 348 is provided for that purpose. 5 Modulator 349 is not required, of course, when video receiver 303a connects to the baseband port of a television.

In the example described above, video receivers 303a-303d are each assigned a different channel at which to 10 receive a signal. Manufacture and distribution of these receivers is more economical, however, if they are all designed identically. One solution is to provide these receivers with the ability to be set to any one of the channels transmitted by processor 312. This solution is 15 provided by demodulation channel control 347, as described in the following paragraph.

Some demodulation devices, known as agile demodulators, can demodulate signals of varying carrier frequencies. That is, these demodulators can vary their 20 demodulating frequency. A cable converter box that presents its output in basebanded form is one example of such a device. Demodulation channel control 347 provides this adjustment capability to demodulator 346, using known techniques. Demodulator 346 can be equipped with 25 electronics to create any of the local oscillators necessary to demodulate the signals it will input. In this case, demodulation channel control 347 can simply communicate to demodulator 346 the identity or frequency of the l.o. (local oscillator) to be used. Alternatively, 30 control 347 can actually supply the l.o. to demodulator 346.

Part I of this disclosure describes some of the advantages of using FM for encoding video signals. It will be appreciated that demodulator 346 can embody well known 35 FM demodulation techniques (if such an arrangement is desired, and if processor 312 and/or video transmitters 304

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provide FM video signals), as well as AM techniques.

Fig. 15B shows an alternative embodiment of RF converter 345' that does not include demodulation but has automatic gain control (AGC). Signals are passed from 5 coupling network 342 (Fig. 13) to gain control 351 which is part of AGC (automatic gain control) circuitry 350. Gain control 351 adjusts the level of the signal. This adjustment is made according to a signal set by integrator/comparator 352.

10 Integrator/comparator 352 creates its signal by measuring the signal energy output by gain control 351 and comparing it to a signal whose level is known to be approximately equal to the desired output level of gain control 351. Deviations of the measured level from the 15 desired level are indications of the amount of adjustment required on the part of gain control 351. These deviations form the signal sent by integrator/comparator 352 to gain control 351.

Filtering may be required by integrator/comparator 20 352 to ensure that the energy it measures derives mainly from energy within the channel of interest. This filtering is performed by filter 356, which receives the output of gain control 351 and feeds integrator/comparator 352.

The signal produced by AGC 350 is sent to mixer 353, 25 which is part of block converter 355. Mixer 353 multiplies the input signal by the output (fundamental) frequency of oscillator 354a or oscillator 354b. The choice between these oscillators is determined by switch 353a (e.g., a manual slide switch similar to the "channel 3/4" switch 30 commonly found on VCRs). Multiplication by the selected oscillator frequency shifts the signal up in frequency by an amount equal to the frequency of the oscillator. (The filtering used to remove one of the two sidebands is not shown.)

35 The result of block converter 355 is conversion of the signal applied to RF converter 345' to a higher

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channel. For example, if the frequency of oscillator 354a is set to 182.8 Mhz, and the input signal is AM modulated with a picture carrier of 22.45 Mhz, when oscillator 354a is selected by switch 353a the output signal will have a 5 picture carrier of 205.25 Mhz, which corresponds to VHF 12.

Block converter 355 includes two oscillators 354a, 354b to help ensure that the signal can be provided to the connected television at a channel that is unused by local broadcasting. As explained in U.S. Patent No. 5,010,399, 10 the U.S. FCC does not allow broadcasting at both of two adjacent channels within the same locality. Thus, using the above example, if the frequency of oscillator 354a is 182.8 Mhz, and the frequency of oscillator 354b is 188.8 Mhz, the output signal can be provided with a picture 15 carrier of 205.25 or 211.25, i.e. VHF channel 12 or 13.

Note that because RF converter 345' does not remodulate the signals applied to it, it should not be used when the applied signals are FM because typical televisions are constructed to receive AM rather than FM signals.

20 In addition to the two embodiments shown herein, U.S. Patent No. 5,010,399 describes several embodiments of transceiver 15 that only detect signals in a single video channel. Because they provide the functions listed above, each of these can suffice for video receivers 303a-303d.

25 Simultaneously Providing Multiple Video Signals to Televisions

A second system of allocating channels that has a number of advantages, described below, is possible when all, or most, video signals are retransmitted via RF/video 30 processor 312 (i.e., when all or most video receivers 303a-303d receive their video signals from transmitters 304a-304c through processor 312, rather than directly from transmitters 304a-304c). This system takes advantage of the fact that all of the multiple video signals 35 simultaneously fed by interface 300 to network 302 will take the same path in transmitting to a particular television. Among other advantages, this feature allows

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the video receivers to provide automatic gain control less expensively. (One advantage is that users may appreciate having several video signals supplied at different channels simultaneously, even though this does not really expand the 5 viewing options.) This system is described in the following paragraphs.

Referring to Fig. 14A, three ranges 340a, 340b, 340c of channels are defined for transmission of signals by RF/video processor 312 and the connected video 10 transmitters. Range 340a includes the five low VHF channels 2 through 6 (in the frequency band of 54 MHz - 88 MHz). Range 340b consists of the frequency band below 30 Mhz. These frequencies are called sub-tunable because they are below 54 Mhz (the lower end of the VHF range). Range 15 340c is divided into two parts; the first part spans the 24 Mhz between 30 Mhz and 54 Mhz, and the second part covers the 24 Mhz between 108 Mhz and 132 Mhz.

In this system of channel allocation, the signals transmitted from RF/video processor 312 to video receivers 20 303a-303d (i.e., "video out") use adjacent channels in range 340b. As described in U.S. Patent No. 5,010,399 and Part I of this disclosure, radiation restrictions imposed by the U.S. FCC relax considerably below 30 Mhz, making that band a good candidate for transmission. In a 25 preferred arrangement, five adjacent 6 Mhz wide AM channels cover this range, with the sound and video information organized according to the NTSC standard. (That standard dictates that the picture carrier be 1.25 Mhz above the low end, and the sound carrier be .25 Mhz below the high end of 30 the channel.) The lowest channel will include frequencies between 0 and 6 Mhz, the second channel will span between 6 and 12 Mhz, etc. The picture carriers of these channels will be at 1.25, 7.25, 13.25, 19.25, and 25.25 Mhz. The electronics will filter out the video energy below 1 Mhz to 35 prevent interference with voiceband communications. The information content at these frequencies is redundant and

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of minimal importance, as described in U.S. Patent No.. 5,010,399.

One advantage of this system is that the maximum number of adjacent channels (i.e., five) are provided below 5 30 Mhz (in range 340b). To fully utilize this system, then, at least five of modulators 327 are provided, with each modulator 327a-327e being assigned a different 6 Mhz band within range 340b.

Referring to Fig. 14B, an alternative allocation of 10 channels in the second range 340b' is presented, because some of the channels in range 340b (Fig. 14A) straddle amateur radio bands that can provide broadcast interference, including the citizen's band at 27 Mhz. Under this alternative, four adjacent 6 Mhz bands are 15 provided, beginning at 3.2 Mhz. (As shown in Fig 4B, a gap appears between adjacent channels. This gap simply indicates that there is unused spectral space between the channels. It does not mean that the channels are not adjacent - they are.) The location of the picture carriers 20 of the four channels 340b' follows the NTSC standard, placing them at 4.45, 10.45, 16.45, and 22.45 Mhz, respectively. This will strategically place the 15 meter amateur radio band between the third and fourth channels and will place the fourth channel under the citizen's radio 25 band at 27 Mhz. The first two channels are low enough in frequency to have sufficient immunity from broadcast interference. A disadvantage is that four channels are provided instead of the five that range 340b provides.

This disadvantage can be eliminated if a 6 Mhz 30 channel is added adjacent and above the uppermost channel in range 340b' (i.e., the channel that has a picture carrier at 22.45 Mhz). The picture carrier of this channel would be at 28.45 Mhz. Although some of the energy of this 35 channel will be concentrated above 30 Mhz, most of the energy will concentrate below. Thus, there is a possibility that, as a practical matter, the channel will

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enjoy the regulatory benefits enjoyed by signals whose energy is concentrated entirely below 30 Mhz. (To avoid overlap with signals in range 340c, the lower two channels in that range could be placed at 34-44 MHz and 44-54 MHz, 5 respectively. Of course, this would reduce their bandwidths by 2 MHz, decreasing the immunity of FM signals in those channels to interference. Another alternative is to not use the 30-42 MHz band in range 340c.)

Range 340a is also known as the low-VHF range. As 10 described in U.S. Patent No. 5,010,399 and Part I of this disclosure, there are always at least two channels in any locality that are not used for local broadcasting in this range. Most commonly, these will be VHF channel 3 and VHF channel 6. The primary use for range 340a is to provide 15 channels for direct transmission between the video transmitters 304a-304c and the video receivers 303a-303d (i.e., video signals transmitted over network 302 in range 340a are not retransmitted to receivers 303a-303d by processor 312).

20 The primary use for range 340c is for transmission between the video transmitters 304a-304c and RF/video processor 312. It is recommended that two 12 Mhz adjacent FM channels transmit in each of the 24 MHz bands (30 MHz-54 MHz and 108 MHz-132 MHz) in range 340c. FM is recommended 25 because its lower minimum SNR (signal-to-noise ratio) requirements may be needed to compensate for interference. Interference can be a problem because F.C.C. rules limit radiation, and thus signal power, more strictly above 30 Mhz, and because significant interference can occur within 30 range 340c.

The 108 Mhz - 132 Mhz band is used because it represents the first opportunity, above range 340a (which ends at 88 Mhz), to find 12 Mhz wide channels that are not likely to encounter significant interference from broadcast 35 sources. (The band between 88 Mhz and 108 Mhz has a high potential for interference because it is used by commercial

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FM radio stations. Television broadcasting does not begin again until 176 Mhz, which is the low end of VHF channel 7.)

The 12 Mhz bandwidth is chosen because it is approximately the width used by inexpensive commercial FM video communication equipment. This is somewhat arbitrary. Indeed, wider bandwidths may be necessary to reduce the minimum SNR required at the input to the video receivers, and to provide sufficient interference rejection. This is especially true at the higher range (108-132 Mhz) where signal attenuation and signal radiation are higher.

To completely specify how signals are transmitted under this system, one must assign every channel in the three frequency ranges 340a, 340b (or 340b'), and 340c to either: (1) video transmitters 304a-304c, or (2) modulators 327a-327e. (To avoid interference, the channels used by the modulators 327a-327e must not overlap those used by the video transmitters.) The preferred system is for each of video transmitters 304a-304c to transmit its signal for retransmission by processor 312 at a different one of the four FM channels in range 340c, and for modulators 327a-327e to transmit at the five adjacent AM channels in range 340b. If extra modulators are provided within processor 312, they can transmit at unused channels in range 340a.

Referring to Fig. 12, each modulator 327a-327e is assigned to perform amplitude modulation within a single frequency band in range 340b, and is set to produce its output signal at the same energy level as all other modulators 327a-327e. These outputs are combined by coupler 331, resulting in a combined signal that includes energy expressed at all of the frequencies within range 340b. This combined signal is fed to amplifier 332, which imparts a gain that is equal at all frequencies of range 340b. This leaves all signals at the same level upon output.

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The gain of amplifier 332 is set so that the video signal with the highest frequency (e.g., the signal in range 340b that has a picture carrier at 25.25 Mhz) generates electromagnetic radiation slightly below present 5 F.C.C. limits. As a result, the gain setting defines the maximum level of the video signals that reach video receivers 303a-303a.

Amplifier 332 imparts the same gain to the four other AM signals in range 340b with picture carriers below 10 25.25 Mhz. Because electromagnetic radiation decreases with frequency, the radiation generated by these signals will also be within the legal limits. Furthermore, because all signals traverse the same path over network 302, those at lower frequencies, which suffer less attenuation per 15 unit length, will be applied to video receivers 303a-303d at higher levels. Thus, if the highest frequency signal meets the minimum level required for quality video, the others also will. If the level of the highest frequency channel (i.e., 25.25 MHz) is not sufficient to reliably 20 communicate quality video, it should be deleted from the allocation system, and the gain of amplifier 332 should be increased so that EM radiation from the signal next highest in frequency falls just below the minimum.

Upon recovery from network 302 of the video signals 25 transmitted by modulators 327a-327e, each receiver 303a-303d processes the signals and simultaneously feeds all of them to televisions 305a-305c and VCR 307, respectively. In one embodiment, video receivers 303a-303d are restricted to processing only video signals fed to telephone wiring 30 302 by RF/video transmitter 312 within range 340b. This provides certain advantages, described below. In another, more general embodiment, each of video receivers 303a-303d can also directly receive (i.e., without retransmission by transmitter 312) all of the signals fed by transmitters 35 304a-304c in range 340a. That is, they can receive signals in range 340a.

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We now describe several alternative designs for video receivers 303a-303d that process only video signals fed to telephone wiring 302 by RF/video transmitter 312. Receivers built according to these designs meet the 5 requirement that they receive all signals within range 340b and provide all of those signals in a form that can be tuned by ordinary televisions and at levels within legal limits. They must also connect to telephone network 302 without disturbing telephone communications, detect 10 infrared control signals, convert them to voltage variations at frequencies above voiceband, and transmit them onto the wiring. Any video receiver meeting these requirements will also fit the description of transceiver 15 of U.S. Patent No. 5,010,399. Video receiver 303a, 15 shown in Fig. 13, was described earlier and it is identical to transceiver 15. Receiver 303a includes RF converter 345, which is labelled "RF converter 19" in U.S. Patent No. 5,010,399. All of the variations in the receiver disclosed in the following paragraphs will be confined to specific 20 embodiments of RF converter 345. Video receiver 303a, shown in Fig. 13, was described earlier, and follows the design of transceiver 15. The variations in the receivers disclosed in the following paragraphs will all be confined to specific embodiments of RF converter 345.

25 Figure 15b shows RF converter 345'. Use of that converter by video processor 303a to receive AM NTSC video signals was described above. The design of converter 345' makes it well suited, however, for use when video receiver 303a receives signals only from processor 312. 30 Specifically, RF converter 345' can convert all of the channels in range 340b to tunable channels with a single block conversion. This is done as follows.

Incoming signals from coupling network 342 (Fig. 13) are applied to automatic gain control (AGC) 350, which 35 automatically adjusts the signal level to be within a range acceptable to most televisions. As described above,

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integrator/comparator 352 measures the output of gain control 351 and subtracts that level from the input signal.

Circuitry 350 performs AGC by applying the same gain to all the video signals passing from coupling network 342, 5 and sets the gain so that the level of the signal with the lowest frequency is just below the maximum permitted level (described above). If, for example, the lowest frequency signal transmitted by processor 312 is one with a picture carrier whose frequency is 7.25 Mhz in range 340b (Fig. 10 14a) AGC 350 sets the gain so that the level of that signal is slightly below 15dB mV. That value is the limit on the conducted output that can be furnished to a TV set by the FCC in the U.S. Because signals transmitted at the higher frequencies suffer greater attenuation as they transmit, 15 their levels will also fall below this limit.

To set the gain in this manner, AGC filter 356 confines the input to integrator/comparator 352 to a narrow band centered at 7.25 Mhz, and integrator/comparator 352 compares this signal to a reference level of 15dB mV.

20 A potential problem can arise if the difference between the levels at the lowest and highest frequencies in the transmission frequency band used by RF/video processor 312 is greater than 15dB mV. In that event, when the level of the lowest frequency signal in the band is set to 15dB mV, the level at the highest frequency signal in the band falls below 0dB, the level below which video quality will noticeably degrade. One solution is to apply a sloped gain that is higher at higher frequencies. For example, assume 25 that due to higher attenuation at higher frequencies, the signal sent by RF/video processor 312 with a picture carrier at 25.25 Mhz is applied to AGC 350 with a level of 10 dB mV, and the video signal sent by processor with a picture carrier at 7.25 Mhz is applied to AGC 350 at a level of 30 dB mV. If gain control 351 is set to attenuate 30 signals at 25.25 Mhz by 10dB, to attenuate signals at 7.25 Mhz by 15dB, and to vary linearly between those limits,

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then both signals will be below the legal limit, yet will also be equal to or above the level of minimum quality.

Ideally, a fixed slope can be found that will be adequate for all residences. Even if no such slope exists,
5 providing a variable slope, set manually or automatically, is far less complex than performing an AGC on each individual channel. Gain control 351 can be designed to provide a gain with a fixed slope or variable slope using known means.

10 When no legal limits apply, it is preferred that AGC 350 set the level of the highest frequency signal to 0dB re mV. This level is just above the minimum required for quality video. Because the lower frequency signals attenuate less, they will also be above the minimum.

15 Signals produced by AGC 350 are applied to block converter 355, which imparts a single upward shift in frequency to all of its input signals. The amount of this upward shift is determined by the local oscillator. This oscillator is selected by switch 353a, which chooses
20 between oscillator 354a or 354b. The shift is such that each signal in the output falls within a channel tunable by ordinary televisions. For example, if oscillator 354a is at 186 Mhz and is selected by switch 353a, an AM signal with picture carrier at 25.25 Mhz would be shifted to VHF
25 channel 13 (at 211.25 Mhz). A little thought reveals that block converter 355 would shift the other four signals in range 340b to VHF channels 9 through 12, respectively.

To preserve the adjustment of AGC circuitry 350, block converter 355 does not change the energy level of the
30 signals that are applied to it. (Alternatively, gain control 351 can adjust its gain to reflect an anticipated gain, or loss, in block converter 355.) It is also feasible to permute AGC 350 and block converter 355, performing gain control after conversion.

35 Switch 353a allows the user to vary the frequency shift of block converter 355 so that the user can more

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easily find five consecutive channels that are unused for broadcasting. Referring to Fig. 15B, if the frequency of oscillator 354a is set to 186 Mhz and that of oscillator 354b is set to 180 Mhz, switch 353a allows the user to 5 choose an upshift to VHF channels 8-12 in place of channels 9-13, simply by selecting oscillator 354b. This has a significant advantage over a fixed upshift. Specifically, it enables the user, in some situations, to switch to a band where more of the channels are empty, i.e. not used 10 for local broadcasting. If a third oscillator is provided at 174 Mhz (together with a three position switch 353a), the option to select VHF channels 7-11 can be added. Another alternative is to set oscillators 354a, 354b to frequencies that provide shifts to ranges in the UHF TV 15 band (it may be easier to find five adjacent UHF channels that are not used for broadcasting).

In the procedure described above, RF/video processor 312 transmits signals at adjacent 6 Mhz channels below 30 Mhz in range 340b, and video receivers 303a-303d convert 20 these signals to tunable channels using a single block conversion 355. No other video signals are produced by the video receivers.

A more general embodiment is to have at least one video transmitter 304a-304c feed its signal onto network 25 302 within a channel in range 340a (i.e. channels between VHF 2 and VHF 6) and to allow video receivers 303a-303d to receive such signals directly, in addition to receiving and processing signals in range 340b as described above. Direct transmission of a signal in this manner has an 30 advantage because it requires the use of only one of the channels available on network 302. This is in contrast to the retransmission technique that requires a signal to use two channels: one channel during transmission to processor 312, and another during transmission to video receivers 35 303a-303d.

Under this alternative, however, adjusting the

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signal levels within video receivers 303a-303d is more complicated, because different signals are typically transmitted over different path lengths of telephone wiring 302. This means that the identity of the strongest signal 5 will not be known unless all signals are measured, and there will not, in general, be a monotonic relationship between signal level and increasing frequency. (By contrast, when all signals are transmitted at the same energy level from the same point -- such as processor 312 - 10 - the signal lowest in frequency will always be received with the highest level.) It also opens up the possibility that the signals will be received by video receivers 303a-303d at levels differing by much more than 15dB mV. As shown above, this means that if a single gain is applied to 15 set the highest energy signal at the legal limit, the lowest energy signal will fall below the minimum required level.

One possible (but relatively complex) solution is to provide an AGC for each channel. A simpler solution is 20 to have gain control 351 (Fig. 15B) adjust gain so that the total energy of all the signals is set at 15dB mV, or whatever the legal limit is. AGC 350 will respond in this manner if filter 356 is broadened to allow passage of the frequencies of all the signals that will be provided to the 25 connected television. For example, assume signals reach a video receiver 303a over three different channels with levels of 25dB mV, 20dB mV, and 16dB mV. The total energy measured by integrator/comparator 352 in this example will be 30.5 dB mV. Thus, gain control 352 will apply a gain of 30 -15.5 dB, leaving the lowest-level signal at 0.5 db mV, still above the 0 dB mV minimum. Fig. 15C illustrates another alternative RF converter 345'' that embodies an approach to the technique just described, which is more likely to provide each signal above the minimum and below 35 the legal maximum level. Converter 345'' performs separate gain adjustments on the low-VHF signals (i.e., the signals

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in band 340a) and the signals below 30 Mhz (in range 340b). Video signals emerging from coupling network 342 (Fig. 13) are applied to splitter 359 (which includes a pair of bandpass filters), which passes signals below 30 Mhz to AGC 350 and block converter 355 (these devices, in turn, process the signals in range 340b in the same manner as that described above). Splitter 359 directs signals in range 340a (the low-VHF channels) to AGC 357, which imparts a gain selected so that the total energy of the signals in range 340a meets a fixed limit. The output of AGC 357 passes to coupler 358, where it is combined with the output of block converter 355. All signals produced by coupler 358 are applied to television receiver 305a.

By dividing the signals in this manner and applying separate AGC to each, the difference between the highest and lowest energy signals in each range 340a, 340b is likely to be less, because there are fewer signals in each group and the gain control is tailored to each frequency range. For example, assume processor 312 transmits 6 Mhz wide NTSC signals with picture carriers of 7.25 Mhz, 13.25 Mhz, and 19.25 Mhz that are received by video receiver 303a with levels of 25dB mV, 20dB mV, and 16dB mV, respectively. Further, assume video transmitters 304a and 304b apply signals at VHF 3 and VHF 6, respectively, to network 302 and that each signal is received at video receiver 303a at a level of 10dB mV. AGC 350 applies a gain of -15dB to the lower frequency signals, as described above (which reduces the levels of the three video signals in range 340b to 10dB mV, 5dB mV, and 1dB mV, respectively). AGC 357, meanwhile, measures a level of 16dB mV in the low-VHF range, and responds by imparting a "gain" of -1dB, leaving the two signals at 9dB mV.

RF converter 345'' of Fig. 15C can also be used if processor 312 (rather than video transmitters 304a-304c) uses the low-VHF channels. For example, let video transmitters 304a and 304b each transmit a signal to

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processor 312 using channels in range 340c, and let processor 312 transmit signals at VHF 3 and VHF 6 (in range 340a) in addition to the channels in range 340b. In this situation, all signals reach video receiver 303a by 5 following the same transmission path. Thus, the signals attenuate in a predictable manner (i.e., the higher frequency signals attenuate more than signals at lower frequencies). This means that separating the channels according to high and low frequencies (e.g., ranges 340b 10 and 340a), as is accomplished in Fig. 15C, is likely to create two groups of signals that have similar levels. Thus, AGC 350 and AGC 357 are even more likely to provide all of their output signals at levels above the minimum required for quality video, and below the limit imposed by 15 regulations.

Control Signal Processing (Fig. 16)

Users who view a television signal (such as at TV 305a) from a remote video source (e.g., a VCR 307 located in another room in the residence) can exercise control over 20 that source using the control signal communication system described in U.S. Patent No. 5,010,399 and Part I of this disclosure. In the typical arrangement, described therein, a video receiver (e.g., receiver 303a) detects the infrared signals (produced by hand-held control device 307') 25 intended to control VCR 307. Receiver 303a converts the infrared signals to voltage variations at frequencies above voiceband, and transmits them across telephone wiring 302. The video transmitter connected to the video source (such as transmitter 304b for VCR 307) detects the electrical 30 version of the control signal on network 302, reconverts it to baseband, and recreates the infrared light patterns with enough strength to excite VCR 307.

As explained in U.S. Patent No. 5,010,399, control signals from infrared transmitters have less information 35 content than video signals and can, therefore, be accurately received at a much lower SNR within any given

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bandwidth. Thus, the choice of a transmission band for these signals is somewhat arbitrary. Because of how the video signals are distributed, however, the only available frequency bands below 132 Mhz are the band between 72-76 5 Mhz and the band above voiceband and below approximately 1 Mhz. (The limit of 1 Mhz is approximately where the lower vestigial sideband of the first channel in range 340b can be cut off.)

Communication between video receivers and video 10 transmitters does not, however, provide a system for communication between a viewer and RF/video processor 312. Such communication is desired to allow a viewer to select a particular signal from incoming cable TV signals at port 315. Interface 300 includes two methods of providing such 15 communication. One method, described in this section, is implemented by control signal processor 330, which is part of processor 312. That component receives control signals sent over network 302, and feeds them to master controller 316. The other method, described in the next section, is 20 implemented by low frequency processor 311 (Fig. 11). That component detects DTMF signals, allowing viewers to send signals to controller 316 using a telephone.

Control signals from infrared transmitter 307' are received and interpreted by processor 312 in the following 25 manner. The signals are detected by video receiver 303a, converted to voltage variations, used to modulate a carrier at a frequency above voiceband, and fed to network 302. The electrical control signals transmit across the wiring of network 302 and are applied to processor 312 via high- 30 pass filter 313 (Fig. 12). In processor 312, the control signals ("control in") pass through coupler 325 and bandpass filter 334 to control signal processor 330.

Referring also to Fig. 16, demodulator 339 demodulates and filters the control signals recreating the 35 basebanded, electrical version of the original infrared light pattern. These filtering and conversion processes

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are described in greater detail below. The baseband electrical version of the control signals are digitized by digitizer 324 so they can be transmitted to and interpreted by the digital circuitry of controller 316. Means to accomplish this digitization in a meaningful manner are used in common universal infrared control transmitters. A description of one technique for accomplishing this digitization is described below.

Transmitter 307' communicates with VCR 307 using eight bit sequences, i.e., every instruction is associated with such a sequence. A "one" bit is transmitted when transmitter 307' generates rapid IR pulses (e.g., 40,000 pulses per second) over an interval of 0.001 seconds. A "zero" bit is indicated by a lack of pulses during the interval. Common infrared remote control devices operate in a similar manner, only with varying pulse rates and interval lengths.

The result of the demodulation of the electrical version of this signal within processor 330 is a waveform with energy that is spread, approximately, over frequencies between 1 Khz and 120 Khz. (This frequency range assumes that the highest frequency is the third harmonic of the 40 Khz pulse rate. The lowest frequency is approximately 1KHz, which is the recurrence rate of the bit pattern.) Digitizer 324 samples this waveform at a rate higher than 240 Khz (the Nyquist frequency) and then rectifies and averages to produce a bilevel signal. This signal is then sampled at the .001 second interval, recreating the original series of "zeros" and "ones." This digital bitstream is transmitted to controller 316 over communication link 330'.

Two pieces of information are communicated between the remote sites (e.g. receiver 303a) and processor 312. One piece of information determines the action to be taken, e.g., selecting a new video signal. The other piece of information indicates which of modulators 327a-327e is to

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respond, e.g., transmit the newly-selected signal. For example, assume that modulator 327a in RF/video processor 312 supplies its video signal within a 6 Mhz NTSC channel whose center frequency is at 7.25 Mhz, and that RF converter 345 (Fig. 13) in video receiver 303a converts the energy in that channel to VHF channel 12 and provides it to television 305a. If the viewer wants to view a different signal (e.g. a different cable channel), the signal sent by that viewer (using remote control 307') must include both the identity of the new signal and an indication that the new signal is to be transmitted from the modulator that uses the 7.25 Mhz channel.

One method of communicating the identity of the particular modulator 327 that provides its signal within the channel is to encode that information in the signal issued by the transmitter. For example, the first three digits of the eight bit pattern described above can indicate the modulator identity by the following simple association:

000 - modulator 327a
001 - modulator 327b
010 - modulator 327c
011 - modulator 327d
100 - modulator 327e

The remaining 5 bits can be used to identify the new channel.

A preferred method is for each video receiver 303 to indicate the identity of the associated modulator 327 by transmitting a simple sinusoid at a specified frequency at the same time it transmits the control signal. Under this system, processor 312 identifies the correct one of modulators 327 by detecting this sinusoid. For example, each of video receivers 303 can transmit its control signal between 72-76 Mhz in the ordinary manner, and simultaneously transmit a sinusoid at a different frequency.

The following table illustrates an example of a set of associations that can be used:

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<u>Modulator</u>	<u>Video Receiver</u>	<u>Frequency</u>	<u>Signal</u>
modulator 327a	303a	0-6 Mhz	.5 Mhz sinusoid
modulator 327b	303b	6-12 Mhz	.6 Mhz sinusoid
5 modulator 327c	303c	12-18 Mhz	.7 Mhz sinusoid
modulator 327d	303d	18-24 Mhz	.8 Mhz sinusoid
modulator 327e	303e	24-30 Mhz	.9 Mhz sinusoid

With this arrangement, for example, modulator 327b transmits its video signal amplitude modulated between the frequencies of 6-12 Mhz, and video receiver 303b receives video signals in the same channel. Video receiver 303b also transmits the control signals it detects within the band from 72-76 Mhz, and simultaneously transmits a sinusoid at .6 Mhz. (Modification of transceivers, such as 15 video receivers 303, to simultaneously transmit extra signals is described in Part I of this disclosure.)

Demodulator 339 detects the sinusoids and the control signals as follows. Referring to Fig. 16A, signals between .5-1 Mhz and 72-76 Mhz pass through bandpass filter 20 334 and transmit to demodulator 339. These signals are amplified by amplifier 373 and are split six ways by splitter 374, feeding each of the six filters 375a-375f. Filter 375f passes signals between 72-76 Mhz, thus passing the control signal. The output of that filter is passed to 25 demodulation circuitry 377. Using technology described in U.S. Patent No. 5,010,399 and Part I of this disclosure, circuitry 377 basebands the control signal, passing the result to digitizer 324 (Fig. 16) which responds by creating a digital bitstream, as described above.

30 At the same time as the control signals are processed, the outputs of each of the other filters 375a-375e feed detector 376. Detector 376 identifies which of these filters is passing harmonic energy, and provides that information to digitizer 324. Digitizer 324 transmits the 35 bitstream and the identification information to master controller 316. All of this processing can be accomplished using commonly known means.

This system is preferred because it makes it much

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easier to coordinate ordinary remote control transmitters with master controller 316. This is because the identity of the video is provided automatically -- the viewer does not have to train controller 316 to recognize a special sequence, and does not have to deliver such a sequence with each signal. This allows one to use, for example, a single transmitter in different rooms (i.e. with different one of video receivers 303) without being concerned about the identity of the video receiver 303 in each room.

10 Note that communication of infrared signals from video receivers 303 to video transmitters 304 is not affected. This is because video transmitters 304 are not equipped to detect the new sinusoids. Thus, using the above example, video transmitters 304 will demodulate 15 control signals in the frequency band between 72-76 Mhz, but will ignore the sinusoids between .5 - 1 Mhz.

Low Frequency Signal Processor (Fig. 17)

In the above system, users communicate with processor 312 from remote sites (e.g., receivers 303a-303d) 20 through infrared transmitters such as IR remote device 307'. To allow users to communicate with processor 312 through touch tone (DTMF) telephone signals rather than infrared signals, processor 311 is connected to telephone network 302 (via low pass filter 314, Fig. 11) to detect 25 predetermined sequences of touch tones entered by the user on any telephone 310a-310c connected to network 302. This is done in the following manner.

Referring to Figs. 11 and 17, low frequency signal processor 311 is interposed between internal residential 30 telephone network 302 and public telephone network 301. Internal to low frequency signal processor 311, ring detector 363 is connected across the red-green pair with a high impedance so that it will not disturb communications, and measures variations in line voltage using known 35 circuitry. Ring detector 363 detects rings by triggering when a high current is detected on the line, or when a high

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concentration of energy at the ringing frequencies is detected. Touch tone detector 364 (connected across the red-green pair of the incoming telephone line from internal network 302) measures voltage on the line without disturbing communications. Using known circuitry, touch tone detector 364 examines these voltage variations for DTMF signals. Both detectors 363 and 364 control switch/power supply 366, and indicate to that device when a touch tone or a ring is detected.

These elements of processor 311 facilitate touch tone communication between a user and controller 316. For example, using any telephone on network 302 (such as telephone 310a), a user enters a "prefix," which consists of a selected sequence of touch tones, which is detected and recognized by touch tone detector 364. Detector 364 responds by sending a control signal to switch/power supply 366, causing it to temporarily break the connection between public network 301 and residential network 302. This prevents succeeding touch tones from being transmitted over public telephone network 301 (e.g., to the central exchange). Simultaneously, switch/power supply 366 imposes a 50V DC signal across the red-green wire pair from network 302 to sustain power to telephones 310a-310c and allow them to deliver further touch tones and conduct other operations. If detector 363 detects a ring during the interval in which the connection between networks 301, 302 is interrupted, detector 363 sends an indication to switch/power supply 366 to cause it to reestablish the connection to public network 301, allowing the user to answer the call. When touch tone detector 364 does not detect a tone over a preselected time interval, it sends a similar signal to switch/power supply 366 to reconnect public and private telephone networks 301, 302.

After detector 364 senses the prefix, it communicates succeeding DTMF signals that it receives to controller 316' over link 311'. Detector 364 terminates

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the touch tone stream at the time that switch/power supply 366 reconnects networks 301, 302. (Ring detector 363 may, but need not, send its ring detections to controller 316.) The detected DTMF tones sent to controller 316 comprise the 5 commands from the user that are arranged according to any suitable protocol. For example, to select a cable TV channel, the first digit entered by the user after the prefix can designate which of demodulators 326c-326e is to be used, with the TV channel to be selected designated by 10 the following two digits entered by the user.

In addition, two-way communication between controller 316 and modem 317 is provided over link 311'. Communications over link 311' can be conducted using ordinary digital techniques. As a result, controller 316 15 can direct modem 317 to send digital information (applied to modem 317 via link 311') to a remote location over public telephone network 301.

A System for Communication Between
Users and Master Controller 316

20 To provide numerous communication and control functions, interface 300 has two additional capabilities. The first is the ability to "learn" control signals (i.e., commands) fed to network 302, particularly control signals from infrared transmitters 307' that are converted to 25 electrical impulses and fed to network 302. This allows users to communicate with interface 300 by using the common infrared transmitters provided with many audio/video devices. The second capability allows interface 300 to regenerate stored control signals and to transmit them over 30 network 302 to video transmitters 304a-304c. Those devices receive these signals and convert them to infrared light. As a result, processor 312 can control infrared responsive devices connected to network 302.

Control signals are detected and digitized within 35 interface 300 by signal processor 330 (Fig. 16), and then passed over link 330' to controller 316, as described above. Controller 316 stores these digital signals in its

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digital memory, using known techniques. Interface 300 uses this detection, digitization, and storage procedure to "learn" to identify common consumer electronic control signals through a cyclical learning procedure. This 5 procedure is now defined.

Referring to Fig. 18, controller 316 includes digital processor 380, digital memory 381, and buffer 382. Digital processor 380 connects to links 326', 328', 329' to establish one-way communication to control various 10 components of RF/video processor 312 according to procedures described elsewhere in this disclosure. Link 311' establishes two-way communication with processor 311, and with detector 364 and modem 317 in particular. Link 320' connects to processor 312 to provide two-way 15 communication between controller 316 and keypad/display 320. That link also connects directly to message storage area 381a in digital memory 381. Digitized signals arriving over link 330' from processor 330 are stored in buffer 382 that feeds storage area 381b of digital memory 20 381. It will be appreciated that controller 316 operates under programmed control, receiving signals through its various communication lines, and issuing signals in response. As such, master controller 316 can be programmed 25 using well known means. One method is to program controller 316 via communication with keypad/display 320.

Processor 380 begins the cyclical learning procedure when a user enters a preset keystroke sequence on keypad/display 320. Then, in the first step of a learning cycle, the user delivers a first message to digital 30 processor 380 through keypad/display 320. Processor 380 stores this message in storage area 381a.

In the second step of each cycle, controller 316 receives a digitized version of a control signal from processor 330, and associates it with the first message by 35 storing it in a location of storage area 381b that

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corresponds to the storage location in area 381a in which the first message has been stored. This is done in the following manner. A user directs light patterns from an infrared transmitter at one of video receivers 303a-303d, 5 which detects that signal and spreads it across the wiring in electrical form using the techniques described in U.S. Patent No. 5,010,399 and Part I of this disclosure. (During the learning cycle, a video receiver can be located close to interface 300, so as to make this procedure easier 10 for the user.) This control signal is received and digitized by processor 330 and passed to master controller 316 using the reception and digitizing procedure described earlier and shown in Fig. 16. The signal is stored in buffer 382. Processor 380 subsequently transfers that 15 signal to the location in digital memory reserved for the first digitized control signal.

The succeeding cycle stores a message in the second location reserved for messages, and a digitized control signal in the associated location. The procedure continues 20 to cycle through these two steps until, during the first step of a cycle, the user issues a message indicating the end of the learning mode.

After the learning cycle, controller 316 operates in normal mode. When in its normal operating mode, 25 processor 330 digitizes each infrared signal it detects, and feeds it to buffer 382. Processor 380 then compares the digitized signal with signals previously stored. Processor 380 interprets a match as the communication of the message associated with the stored signal. Processor 380 can 30 interpret the lack of a match as a "false alarm," and respond by returning to a quiescent state, waiting for the next detection of a digitized signal from processor 330.

Many types of one-way communication between the user and interface 300 are facilitated in this manner. Using 35 the cyclical learning system very primitively, for example, each key of an infrared transmitter with 36 keys can be

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associated with the 36 alphanumeric characters (26 letters and 10 numbers.) Thus, when the key of the transmitter that issues a signal that processor 380 "learned" to associate with the letter "z" is depressed while in "normal mode," the user of that transmitter will have communicated the letter "z" to controller 316.

The response of controller 316 to a message will be determined by the software in its memory (recorded in storage area 381c) that implements the "programmed control," and will be limited by the power that controller 316 can exercise over the elements of the system. As described earlier, the controller 316 can, among other things, instruct graphical processors 329a-329e to overlay any alphanumeric character on each of the signals sent onto network 302, and it can also control the signal selected and basebanded by modulators 326a-326e. As will be described below, controller 316 can also send control signals to infrared responsive video sources connected to video transmitters 304a-304c. Thus, the software of controller 316 can implement many different communication/control algorithms. An example will be described shortly.

An alternative to the cyclical learning system is to have processor 380 store a digital representation of the waveforms of control signals from a large number of common transmitters. A list of these signals can be provided in the documentation manual of interface 300. Then, using keypad/display 320, a user can "teach" processor 380 by issuing instructions to associate a particular message with a particular digitized signal. Then in normal operating mode, processor 380 operates as before, i.e. the match of a received control signal with a stored signal is interpreted as communication of the message associated with the stored signal, and the program in processor 380 reacts to that message.

Master controller 316 can also transmit control

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signals onto network 302 to control infrared responsive components. This is done as follows. Using the iterative learning process described above, digital representations of control signals are stored in memory 381 of processor 316. Alternatively, these signals can also be stored at manufacturing time. In that case, the signals from many controllers should be stored at once. That would ensure that, in any arbitrary residence, controller 316 is likely to include all or most of the signals that are meaningful to the infrared responsive video devices connected to the network.

In response to a particular stimulus, the governing program of controller 316 transmits the digital representation of an analog waveform across communication link 330' to control signal creation processor 338, shown in Fig. 16. Inside processor 338, standard digital to analog circuitry 360 recreates the basebanded analog waveform from the digital representation. The analog signal is then used by modulator 361 to modulate a carrier at an RF frequency. The preferred frequency of the carrier is the same one used for transmission of control signals by video receivers 303a-303d. This provides the economy that video transmitters 304a-304c need only be equipped to detect signals with a single carrier. The preferred band for this carrier is 72-76 MHz, as described above. The modulated signal is then amplified by amplifier 362. The modulation and amplification techniques and parameters necessary for transmission across the wiring are described in U.S. Patent No. 5,010,399 and Part I of this disclosure.

It will be appreciated that the frequency band used for control signals generated by circuitry 338 is the same as that used by control signals applied to demodulator 339 from network 302 (i.e., 72-76 MHz). To avoid the control signals produced by circuitry 338 "wrapping around" and being applied to controller 316 via demodulator 339, detector 338' opens switch 339' whenever control signals

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are generated by circuitry 338.

After amplification, the signal is passed through bandpass filter 336, coupler 325, high pass filter 313 and onto network 302. The video transmitters 304a-304c connected to network 302 will detect these signals and use them to recreate the infrared patterns to which the certain signal sources respond. Note that, when the same carrier is used to modulate the control signals within both processor 312 and video receivers 303a-303d, filter 336 will be identical to filter 334. Two filters and two paths are shown in Fig. 16, however, to show the more general design that obtains when different carrier frequencies are used by processor 312 and the video receivers 303a-303d.

Following is an example of communication and control using the two new features described in this section. Assume that modulator 327b transmits its output AM encoded and between the frequencies of 6 and 12 Mhz, and that video receiver 303a is tuned to detect AM video signals in the same 6 Mhz channel and to provide them to television 305a. A viewer watching television 305a uses an infrared transmitter whose command set has been "learned" by controller 316. Using signals "learned" by the software, this viewer communicates to controller 316 that VCR 307 should begin recording VHF channel 4 at 4 PM. Controller 316 "echoes" this message onto television 305a by instructing graphical processor 329b to overlay the alphanumeric characters "RECORD channel 4 at 4 PM" on the signal it outputs to modulator 327b. Finally, processor 380 transmits the "change to channel 4" signal and the "record" signal of VCR 307 to video transmitter 304b at 4 PM. Transmitter 304b responds by issuing that signal in infrared form to VCR 307.

As described, the power to detect infrared control signals, store them, and reissue them makes RF/video processor 312 a powerful device when operating under programmed control. Many possibilities are available to a

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user that programs such a device. One possibility in particular appears to have interesting potential. That is the possibility that any single infrared transmitter can be given the power, via processor 312, to control all of the 5 infrared responsive devices connected to the network. To provide this capability, controller 316 is first taught the command sets of the infrared responsive devices. This can be done using the learning cycle described earlier. Then, controller 316 is taught the commands of the infrared 10 transmitter that is to receive enhanced capabilities. Finally, controller 316 can be programmed, via keypad/display 320, to associate signals from the enhanced transmitter with those of other devices.

Interactive Video Communication (Fig. 12)

15 Another important advantage of routing all video signals through a single RF/video processor 312 is that a single device, i.e. processor 312, can cause graphics and text to be overlaid on any of the video signals sent over network 302 to televisions 305a-305c. Using known 20 processing techniques, digital information representing a graphical image of virtually any size, shape, and color can be combined with an unmodulated analog video signal, generating a picture in which the graphical image overlays the picture provided by the analog signal. Digital 25 electronics can also, of course, provide a complete video signal, as interactive video games do.

Digitally encoded images are selectively added to the transmission system by graphical processors 329a-329e, which are interposed between video switch 328 and 30 modulators 327a-327e, respectively. Each graphical processor 329a- 329e can receive a different digital representation of an image from controller 316 over communication link 329'. (Controller 316 generates this information using known techniques available to devices 35 with programmable logic and digital memory. Any of the "input" stimuli provided to controller 316, such as control

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signals from processor 330, signals from keypad 320, and DTMF signals from processor 311 can be programmed to cause controller 316 to take any particular action, including overlaying graphics.) Typically, this information will 5 include text, such as a graphical image that indicates the identity of the channel from cable TV feed 315a that is being transmitted.

Graphics processors 329a-329e combine the graphical information from controller 316 with the unmodulated video 10 signals transmitted by switch 328. The resulting signal, in which the graphics are overlaid on the video signal (i.e., the TV picture), is passed to the corresponding modulator 327a-327e. (Graphical processors 329a-329e can also, of course, pass the video signals from switch 328 15 without adding graphics.) Alternatively, the graphical image provided by controller 316 may fill the entire video screen, completely replacing the signal sent by switch 328.

The introduction of videotext, graphical overlays, and digitally created video signals allows controller 316 20 to communicate with the users in the residence. For example, any digital information stored in controller 316 can be displayed as text on the picture. Also, information downloaded from the public network by modem 317 and passed to controller 316 over link 317' can be displayed on any of 25 the televisions connected to network 302. This information can be graphical in nature, allowing complete pictures to be sent over public network 301 and displayed on the televisions connected to network 302.

RF/video processor 312 can also deliver synthetic 30 voice messages by replacing the sound component of video signals sent to the various televisions. The ability to deliver infrared control signals across the wiring to control the video and other components, as described above, is also a form of communication.

35 To provide communication in the opposite direction, (i.e. between the user at a remote location in the

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residence and interface 300) either DTMF signals from any telephone on network 302 or control signals from infrared transmitters such as device 307' can be used. These communication paths are described above. Thus, a user can 5 issue touch tone sequence "#*3", for example, to indicate "record." Processor 311 detects this sequence, and passes it to controller 316. If a matching command (stored in controller 316 during the above-described learning process) is found, controller 316 responds to the sequence by 10 issuing an infrared signal that commands VCR 307 to begin recording.

As is clear from the above description, master controller 316 acts as the nerve center of the communications system. The DTMF, infrared, video, and 15 modem communication paths allow for many novel applications. The communication paths and control functions are summarized below:

- 20 1) Controller 316 receives touch tone or DTMF signals from telephones on either the residential network 302 or public network 301 by connection to telephone signal processor 311.
- 25 2) Controller 316 receives and transmits digital information from outside the residence via modem 317 which connects to public network 301. This information is provided to controller 316 via communication link 311'.
- 30 3) Controller 330 receives all control signal information transmitted onto the residential network by the video receivers using means described in U.S. Patent No. 5,010,399 and Part I of this disclosure. It digitizes these signals and provides them to controller 316.
- 35 4) Controller 316 controls the video sources by transmitting control signals onto the network. These signals are detected by video transmitters 304a-304c, and used to recreate infrared patterns to which the video sources respond.
- 40 5) In response to the various control signals, controller 316 controls demodulators 326a-326e and switch 328 to select the signals to be distributed to the connected televisions.
- 6) Controller 316 directs graphical processors 329a-329e to overlay graphics on the video signals

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distributed to the video receivers.

Other Embodiments

Other embodiments are within the following claims.

For example, one or more of the multiple signal processing and communication functions that have been assigned to the various components of interface 300 (Fig. 11) can be assigned to other components of the interface without changing the overall functionality of interface 300.

10 In addition, an alternative embodiment of selection and conversion processor 337 (Fig. 12) of RF/video processor 312 is described below.

Alternative Distribution Systems (Fig. 19)

Selection and conversion subprocessor 337 of Fig. 12 includes a considerable amount of processing circuitry and provides many different functions. A converter box that includes a subprocessor with less circuitry and less functions, however, may be more attractive in some applications because it is less expensive. In particular, 20 a converter box that simply provides multiple cable signals without retransmission and without graphical overlays can be very attractive as a retail item and also as a device provided by cable companies. Consumers may wish to purchase such a box to expand their cable TV distribution 25 without buying an expensive or complicated device. Cable companies may prefer this box over others because they are content to limit their service to cable TV signals and leave graphical overlays and VCR and camera signal distribution to the consumer.

30 Fig. 18 shows selection and conversion subprocessor 370 for use in RF/video processor 312 in place of subprocessor 337. Electronically, subprocessor 370 is a subset of subprocessor 337. It is shown in this section because the inventors feel that it may be the most popular 35 design for these types of devices, and because it provides an illustration of how the functionality of the video

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distribution system can be changed by changing the selection and conversion subprocessor.

Cable TV signals are fed to subprocessor 370 through port 315. These signals are split three ways, feeding 5 demodulators 371a-371c (demodulator 371b is shown in detail). Under control of master controller 316, each of demodulators 371a-371c demodulates (and descrambles, if necessary), one of the cable signals. Controller 316 exercises control over demodulators 371a-371c (e.g., tunes 10 the local oscillators within demodulators 371a-371c so that the selected cable TV channels are demodulated) by passing signals over communication links 371'. Because the cable TV signals are AM, conventional envelope detection and filtering is employed by each demodulator after the 15 incoming signal is downconverted.

The basebanded signals produced by demodulators 371a-371c are passed to modulators 372a-372c, respectively. Details of modulator 372b are shown. It will be appreciated that each modulator 372a-372c includes a mixer, 20 a fixed frequency local oscillator (the local oscillator frequencies are all different) and a filter to remove, e.g., the lower sideband produced by the mixer. Modulators 372a-372c thus convert the applied signals to the frequency bands and waveforms (i.e., AM, although by modifying the 25 modulators FM may alternatively be used) at which they will be transmitted across telephone wiring 302. The outputs of modulators 372a-372c are combined by coupler 331 and fed to amplifier 332. After amplification to the level at which they will be broadcast across network 302, the three 30 combined signals are fed through bandpass filter 333 and onto the network. The functions of filter 333 are described above.

Various considerations for the choice of frequency band, waveform, and energy level are also discussed 35 elsewhere in this application and in U.S. Patent No. 5,010,399 and Part I of this disclosure. A preferred

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method of reception is for each video receiver 303a-303d to receive only a single signal within a (channel) frequency band that is determined by a manual setting. A preferred method of channel selection is for subprocessor 370 to 5 determine the signal received by such a video receiver by determining the signal demodulated by the one of demodulators 371 whose output is transmitted over that particular channel.

Using a Second Twisted Pair to Transmit Additional Signals

10 As discussed above, the number of signals that can transmit over network 302 is limited by the increasing attenuation of energy at the higher frequencies. In most residences, however, the telephone wiring consists of several twisted pairs. Each of these pairs typically 15 branches off to connect to each of the jacks in the residence. One of these pairs, typically the one whose conductors are colored red and green, conducts the signals for the primary telephone service to that unit. Additional pairs are left empty unless and until secondary telephone 20 lines are requested. (The conductors of the second pair are typically colored yellow and black.)

Ordinarily, crossover of energy from one pair to another can create interference, preventing use of these extra wires for transmitting additional signals within the 25 same channels. Part I of this disclosure, however, describes how encoding video signals using frequency modulation can be sufficient to prevent crosstalk interference between two pairs that serve the same unit, thereby preserving the opportunity for transmission of 30 additional signals. Thus, the channels used for FM communication in this application can be used to transmit different signals on different pairs simultaneously, thereby increasing the capacity of the system.

Part I of this disclosure describes the phenomenon 35 of "nearend" crosstalk, however, that requires that signals using the same FM channel on neighboring twisted pairs in

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a bundle to originate at the same point on the wiring network. Thus, the extensions proposed in this section are confined to transmission of FM signals from processor 312.

To adapt processor 312 to use extra pairs, some of 5 modulators 327 can simply connect to transmission paths feeding the second pair. For example, referring to Fig. 12, let modulators 327a and 327b both transmit their signals using the 108-120 Mhz channel of range 340c. To prevent interference, modulator 327a is connected to 10 coupler 331a (not shown) rather than coupler 331. Signals fed to coupler 331a pass through amp 332a, filter 333a, coupler 325a, and filter 313a. These components, which are not shown, are companions to coupler 331, amp 332, filter 333, coupler 325, and filter 313. They are identical 15 (except for coupler 325a); to their companions, and are connected in the same way. Coupler 325a is different because it need only include two ports: the one receiving video signals from filter 333a and the one transmitting video signals through filter 313a. Filter 313a connects to 20 the second pair instead of the pair to which filter 313 connects.

Part III - Two-Way RF Communication at Points of Convergence of Wire Pairs from Separate Internal Telephone Networks

25 A. Overview (Fig. 21a)

Referring to Fig. 21a, the technology described in this application is designed to communicate signals between transceiver/switch 400, located where individual telephone lines from multiple local networks converge for connection 30 to a main telephone trunk 476', and groups of RF communication devices that are connected to the individual local networks 411a-411e of telephone wiring. Each of local networks 411a-411e (collectively "local networks 411") includes the wiring confined to a structure such as 35 a house or to an area within a structure such as an apartment unit or a room in an office building. This wiring provides a single conductive path for a single

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ordinary telephone signal. Thus, in the case of the common four conductor telephone wiring, the red/green pair constitutes one local network, and the yellow/black pair constitutes a second local network. (The only special 5 relationship between these local networks is that they bundle more tightly together than wiring serving different areas. Theoretically, this could increase the crosstalk between the pairs.)

Note that the details of the wiring of local 10 networks 411d, 411e are not shown in Fig. 21a. Those local networks will not be served by the communication system described herein. They are included only to demonstrate that not all local networks within a group whose wires converge at a particular point need participate in the 15 communication system described herein.

The wiring of each local network further includes a single branch that strays far from the structure, ultimately leading to the point of convergence where they connect to (or become part of) trunk 476'. These are 20 extended pairs 405a-405e, (collectively, extended pairs 405.) The extended pairs 405 from each of local networks 411 may be bundled closely together near the point of convergence.

When transceiver/switch 400 is installed, extended 25 pairs 405 are broken near the point of convergence, with transceiver/switch 400 interposing between the two ends of each pair. One segment of each pair remains connected to trunk 476'. These segments are called twisted pairs 476a-476e, (collectively, twisted pairs 476.) Thus, 30 twisted pairs 476 and their associated extended pairs 405 ordinarily constitute an uninterrupted connection between local networks 411 and local telephone exchange 475. In the system described herein, transceiver/switch 400 interposes between these wires to provide a link between 35 communication line 402 and local networks 411. As will be described below, one of local network interfaces 404a-404c

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may also interpose along this path, in the middle of or at the opposite end of the corresponding one of extended pairs 405.

Communication line 402 provides high capacity 5 communication (such as for cable TV signals) with remote locations. Line 402 includes one or more coaxial cables, optical fibers, or the like. Transceiver/switch 400 connects to line 402 to receive and transmit signals. It processes the signals it receives, and switches them onto 10 selected ones of extended wire pairs 405 leading to local networks 411, together with (and without interfering with) the telephone signals (e.g., voice signals) that also use those wires. The switched signals are received by the RF communication devices connected to local networks 411.

15 Transceiver/switch 400 also receives video, digital, control, and other types of signals from extended pairs 405. These signals, which normally originate in the areas served by the local networks 411, are applied to local networks 411 by the connected RF communication devices, and 20 transmit across extended pairs 405 to transceiver/switch 400.

Local network interfaces 404a-404c (collectively, interfaces 404) are respectively interposed on extended pairs 405a-405c, thus connecting between transceiver/switch 25 400 and the corresponding local networks 411. Typically, they will be located at a part of extended pairs 405 that is closer to the corresponding local network 411, rather than transceiver/switch 400. They assist in the transmission of signals in both directions between 30 transceiver/switch 400 and local networks 411, as described in more detail below.

Each local network interface 404 intercepts signals sent from the corresponding extended pair 405, applies amplification and/or other signal processing, and feeds the 35 resulting signal onto the corresponding one of local

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networks 411. This assists in the transmission between transceiver/switch 400 and local networks 411. Each local network interface 404 also performs a similar function to assist signals that are transmitted in the other direction, 5 i.e., by receiving signals from one of local networks 411 for transmission to transceiver/switch 400 via one of extended pairs 405.

As is emphasized at several points in this document, local network interfaces 404 need not be used in some 10 conditions, particularly when extended pairs 405 are relatively short, e.g., less than 300 feet in length. Such is often the case in apartment buildings. This is fortuitous because there is often no opportunity to interpose a device between the point of convergence and the 15 telephone jacks in an apartment unit when a transceiver/switch is located in the wiring closet on each floor of the building. (When the point of convergence is a room in the basement where all the twisted pairs converge, the wiring closets are good locations for local 20 network interfaces, as is described in greater detail below. A communication system is shown in Fig. 21b and described later on that does not include local interfaces 404.)

The communication devices connected to local 25 networks 411 are now described. Video receivers 419a-419c and 419a', video transmitters 417b-417c, digital transceiver 491c, and telephone devices 414a-414c (collectively, telephone devices 414) all connect to local networks 411a-411c as shown in Fig 1a. Except for 30 telephone devices 414, all of these devices communicate RF signals over local networks 411, and are referred to herein as RF transmitters and RF receivers. The RF signals they apply to local networks 411 are received by local network interfaces 404 and retransmitted across extended pairs 405. 35 (These signals can also be received by other devices

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connected to local networks 411.) Any number of RF transmitters and receivers and telephone devices can connect to any one of local networks 411.

Each of telephone devices 414 connects via a low-pass filter (LPF). As described in Part I of this disclosure, these filters prevent telephone devices 414 from affecting RF energy on the local networks 411. These filters may be provided as part of splitter 161, which is described in Part I of this disclosure.

The video transmitters and receivers are those described in U.S. Patent No. 5,010,399 and in Parts I and II of this disclosure. Video receivers 419a-419c and 419a' (collectively, video receivers 419) connect to televisions 492a-492c and VCR 498a, respectively. Video receivers 419 also detect infrared (IR) light signals, convert them to equivalent electrical signals, and apply them to the corresponding one of local networks 411. These signals transmit across extended pairs 405 to transceiver/switch 400 for purposes described in detail below. Infrared transmitters 493a-493c (collectively, infrared transmitters 493), are respectively provided at local networks 411a-411c to produce the IR signals.

Video transmitter 417b connects to video camera 494b. It derives a video signal from that device, processes the signal, and applies it to network 411b. Camera 494c connects to video transmitter 417c which connects to local network 411c and operates in a similar manner. Transmitters 417b and 417c also receive the control signals applied to their associated local network 411. They convert these signals to infrared signals equivalent to the original signal, then broadcast them out into the vicinity for reception by nearby infrared responsive devices.

Digital transceiver 491c connects between a computer 35 495c and local network 411c. It receives digital signals

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from the network wiring and transmits them to computer 495c, and it also receives signals from computer 495c and applies them to the wiring. Digital transmitters and receivers are described in Part I of this disclosure. That 5 application also describes how to combine RF transmitters and receivers into a single device that communicates through a single connection to active telephone wiring.

Except for control signals meant to communicate with transceiver/switch 400, the non-telephone signals received 10 from extended pairs 405 by transceiver/switch 400 are fed to line 402 for transmission to other communication devices that connect to line 402 at locations removed from transceiver/switch 400. One application for this is to establish a simple two-way videoconference between two 15 people located near opposite ends of communication line 402 or at two points of line 402 that are far from each other.

In the reverse direction, transceiver/switch 400 can transmit any of the signals (such as cable TV signals) selected and recovered from communication line 402 over any 20 one of the extended pairs 405, without disturbing the telephone signals that also use those wires. A single selected signal (e.g. an ordinary NTSC television signal) can be assigned to more than one pair, and several signals can be assigned to the same pair.

25 The processing performed by transceiver/switch 400 on the signals it recovers from communication line 402 converts those signals to the waveform (e.g. the modulation type such as AM or FM) energy level, and frequency band at which they will be effectively transmitted onto wire pairs 30 405. These signal characteristics must be such that the signals will communicate with high fidelity over extended pairs 405a-405c to the RF communication devices connected to local networks 411a-411c. The relationship between these signal characteristics and the success of this 35 communication is discussed at length below.

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The selection of the signals from line 402 and their assignment to particular ones of extended pairs 405a-405c (and thus their assignment to the various local networks 411a-411c) is made by transceiver/switch 400 in response to 5 the control signals sent from local networks 411 over extended pairs 405. Transceiver/switch 400 also receives and responds to control signals from communication line 402, which can give the originator of those signals partial control over signal distribution to local networks 411.

10 The signals from local networks 411 to which transceiver/switch 400 responds in making selections are known as "control" signals and are sent by subscribers using infrared transmitters 493. Using techniques partly described in U.S. Patent No. 5,010,399 and Parts I and II 15 of this disclosure, video receivers 419 detect these infrared signals, convert them to electrical signals and apply them to local networks 411. These signals then transmit to transceiver/switch 400, as is described below. Control signals from local networks 411 can also be 20 generated by other means, and applied to local networks 411 by other RF communication devices. The digital transmitters described in Part I of this disclosure, for example, can respond to manual inputs to transmit an electrical signal(representing binary information) onto 25 local networks 411. This electrical signal can be used to communicate a channel selection to transceiver/switch 400.

Following is an example of how this system is used to communicate video and control signals. First, assume 30 communication line 402 conveys 30 video signals from a local cable TV franchise. According to the invention, transceiver/switch 400 selects one or more (typically one or two) video signals from among those 30 to be sent to, for example, local network 411a. Transceiver/switch 400 transmits the selected video signals over extended pair 35 405a to local network interface 404a. Interface 404a

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receives these signals and retransmit them onto local network 411a, where they will transmit to video receivers 419a and 419a' and be provided to TV 492a and VCR 498a. Other RF receivers that connect to local network 411a can 5 also receive these signals.

Viewers of television 492a connected to local network 411a via video receiver 419a, meanwhile, can use transmitter 493a to issue infrared control signals to determine which signals are selected and transmitted to 10 local network 411a. Video receiver 419a detects these infrared patterns, converts them to electrical signals, and applies them to local network 411a. These electrical signals are received by local network interface 404a which processes them and relays the signal across extended pair 15 405a to transceiver/switch 400. These signals indicate to master controller 415 (Fig. 22) the identity of the cable TV signals that are to be sent to local network 411a. Alternatively, signals from communication line 402 detected by master controller 415 can also determine the identity of 20 the cable signal to be sent to local network 411a.

The viewer can also transmit video signals from a local network 411 to communication line 402. This can be useful for any number of purposes, the most simple of which is to add pictures to an ordinary two-way telephone 25 conversation. An example of this is where the signal from video camera 494b is applied to local network 411b by video transmitter 417b. That signal will transmit over local network 411b to local network interface 404b. Local network interface 404b receives the video signal and 30 transmits it across extended pair 405b to transceiver/switch 400 which will apply the signal to communication line 402. (Again, local network interface 404b will facilitate this communication only if it is included in the system.)

35 There can be a large variation in the lengths of

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extended pairs 405. In an apartment building, the telephone wires serving different units may converge at a point 100 feet or less from each apartment unit. An example of the other extreme occurs when distributing 5 signals to separate houses in a neighborhood. In this case, connecting ten houses to the a single transceiver/switch 400 may mean that some of extended pairs 405 will be longer than, perhaps, 1000 feet.

Unfortunately, attenuation of the video signals 10 increases with frequency, which means that the highest useful frequency on extended pairs 405 decreases with length, ultimately restricting the signals to below 4 Mhz. This is a problem because 4 Mhz of bandwidth is the approximate minimum required for transmission of an NTSC 15 video signal in analog form. The inventors estimate that this point occurs before the lengths of extended pairs 405 reach 3000 feet.

The solutions described herein take advantage of the improved ability of RF (radio frequency) signals to 20 transmit over longer distances at lower frequencies to avoid problems due to the lengths of extended pairs 405. The invention also takes advantage of the property of conducted RF transmission that dictates that the tendency for energy from a signal on one wire pair to cross over to 25 a neighboring pair decreases as the frequency of the signal decreases. This crossover, which can cause interference, is likely to result when pairs 405 are closely bundled within a common sheath, as often happens. Finally, the ability of frequency modulated (FM) signals to resist 30 interference to a greater degree than amplitude modulated (AM) signals with more narrow bandwidths also plays a part in the system design.

The next part of the disclosure describes the signal flow between major components internal to 35 transceiver/switch 400, and the processing performed by

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those components. That section is entitled "Signal Flow and Signal Processing in Transceiver/Switch 400." One of the major goals of this processing is to convert signals from the form provided by communication line 402 to the waveform, frequency band, and amplitude useful for successful communication across one of the extended pairs 405a-405c. The requirements for these characteristics are described in the section entitled "Transmission of Wideband Signals Over an Extended Pair."

10 Two other sections following are entitled "Signal Conversion and Switching in Transmitter/Switch 400" and "Transmission and Recovery of Signals from a Single Twisted Pair in a Bundle." Details of major processing components of transceiver/switch 400 are provided therein. Finally, 15 details of signal processing with in local network interfaces 404 is described in the last section, which is entitled "Signal Processing at the Local Network Interface.

B. "Signal Flow and Signal Processing in Transceiver/Switch 400 (Fig. 22)

20 Following is a description of a general embodiment of transceiver/switch 400. Referring to Fig. 22, the major processing elements of transceiver/switch 400 are processor 418, signal separators 413a-413c master controller 415, low pass filters 474a-474c, and control signal processor 420. 25 Processor 418 serves as the interface to communication line 402, and each signal separator 413a-413c (collectively, signal separators 413) serves as the interface to the corresponding one of extended pairs 405. One of the functions of processor 418 is to select, under the 30 direction of master controller 415, video and other signals from communication line 402, to process those signals, and to feed them to signal separators 413. Another function of processor 418 is to receive video and other signals from signal separators 413, convert those signals to a form 35 appropriate for transmission on line 402, and feed them to communication line 402. A third function is to receive

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signals from any given one of signal separators 413, convert those signals, and to feed them to a different one of signal separators 413, thus establishing communication from one of local networks 411 to another.

5 Each of signal separators 413 is connected between one of extended pairs 405 and the corresponding one of twisted pairs 476. One of the two major functions of each of signal separators 413 is to transmit signals from processor 418 onto one of extended pairs 405. These signals
10 are applied so that they transmit onto extended pairs 405 in the direction of local networks 411. A second purpose of each of signal separators 413 is to recover signals transmitting from one of local networks 411 over the corresponding one of extended pairs 405, and to provide
15 these signals to processor 418. In some embodiments, signal separators 413 also convert telephone signals so that they transmit over extended pairs 405 at frequencies above voiceband.

Each of twisted pairs 476 connects to the "exchange" port of the corresponding one of signal separators 413. In Fig. 22, the "exchange" port is on the left side of signal separators 413, and the "local" port is on the right side. Signals provided by processor 418 to signal separators 413 transmit out the "local" port onto one of extended pairs
25 405 towards the associated one of local networks 411. Signals transmitting from local networks 411 to transceiver/switch 400 flow in the opposite direction. The various ports of signal separators 413 are shown in more detail in Fig. 29a. The details of signal routing within
30 signal separators 413 are described below.

In contrast to the "local" port, only telephone signals flow through the "exchange" ports of signal separators 413. Telephone signals transmit over twisted pairs 476 in both directions, transmitting between local
35 exchange 475 and the "exchange" ports, thus passing through

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low-pass filters 474a-474c (collectively, low pass filters 474) during transmission.

Low-pass filters 474 connect in series on twisted pairs 476 to suppress the higher harmonics of telephone signals transmitting across them. This suppression prevents the higher harmonics of the telephone signals from local exchange 475 from reaching extended pairs 405, where they could possibly interfere with RF signals.

Signal flow between signal separators 413 and processor 418 is now described. There are two conductive paths connecting processor 418 with each of signal separators 413. Paths 478a-478c (collectively, paths 478) conduct signals transmitted by processor 418, and paths 479a-479c (collectively, paths 479) conduct signals transmitted by the associated one of signal separators 413.

The electrical signal, i.e. the voltage variations transmitted to each one of signal separators 413 from processor 418, may include several individual signals at different frequencies that are combined together onto the associated one of conductive paths 478. In response to commands sent from master controller 415, processor 418 determines the composition of each of these combined signals. After transmission to a particular one of signal separators 413, each combined signal continues on to transmit to the corresponding one of extended pairs 405.

Other than switching and filtering, no processing of the combined signal takes place after it leaves processor 418 until it reaches one of local network interfaces 404. Thus, the signal processing performed by processor 418 on the individual signals it selects and recovers from communication line 402 determines the waveform (e.g., AM or FM), frequency, and amplitude at which these individual signals are transmitted across pairs 405.

In the reverse direction, signals transmitted by RF transmitting devices 417 onto one of local networks 411

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transmit to the corresponding one of signal separators 413. (Other devices can also transmit RF signals onto one of local networks 411. An example is any of video receivers 419, which transmit control signals.) The corresponding 5 one of signal separators 413 recovers these signals and, except for control signals targeted for master controller 415, feeds them over the associated one of paths 479 to processor 418. These signals are received by processor 418 and applied to communication line 402. They may also be 10 transmitted to any of local networks 411 that are different from the local network 411 of origin.

Control signals originated by subscribers are fed to local networks 411 within a specific frequency band, and are transmitted to master controller 415, as described 15 below. This provides a method of communication between a subscriber and transceiver/switch 400, allowing the subscriber to control, among other things, the channels that are selected from communication line 402 for transmission to the local network 411 where the control 20 signal originated. In a preferred embodiment, these signals are issued by an IR device 493 as infrared patterns which are detected by video receivers 419, converted to electrical signals, and fed onto the wiring. Other systems of feeding signals onto local network 411 within the 25 particular frequency band can also suffice.

The control signals targeted for master controller 415 are received from local networks 411 by local network interfaces 404 which process them and apply them to extended pairs 405. These signals are recovered from pairs 30 405 by signal separators 413 and fed over the associated one of paths 477a-477c (collectively, paths 477) to control signal processor 420. Processor 420 processes these control signals and communicates them over path 420a to master controller 415.

35 Master controller 415 also receives (via control

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signal processor 420) control signals that processor 418 recovers from communication line 402 and sends over path 420b. In response to these signals and to the control signals it receives from local networks 411, master controller 415 sends signals to processor 418 over links 446a-446e (collectively, links 446). Processor 418 determines the selection of signals from communication line 402 and the composition of the signals fed over extended pairs 405 to local networks 411 in response to signals from links 446.

C. Transmission of Wideband Signals over an Extended Pair

As described above, processor 418 selects signals from communication line 402 and converts them to the waveform, frequency, and energy level at which they are fed to extended pairs 405. These characteristics determine, to a large extent, the ability of video receivers 419 connected to local networks 411 to detect these signals and the ability of extended pairs 405 to conduct more than one signal at a time.

The nature of the communication medium that is the subject of this application presents two particular problems. One problem is that there is a significant possibility of crosstalk interference between the various signals on extended pairs 405. This possibility is high because telephone wires converging at a common point may run parallel and very close to each other for a long distance. This makes interference resulting from crossover of RF energy between the pairs likely. A second problem is that the usefulness of the system is related to the length of the longest path over which communication can succeed. This is a problem because communication bandwidth decreases as the length of a twisted pair communication line increases. (The issue of transmission length will be less important for communication within apartment houses and

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office buildings than they will be for communication with separate residential structures in a neighborhood. This is mostly because the wires of many different networks in an apartment or office building often converge at a point less than 500 feet from those networks.)

In addition to these problems, there are also particular advantages to this medium. In particular, because extended pairs 405 connect directly between transceiver/switch 400 and local network interfaces 404, these wires encounter no splits and no connected telephone devices. Thus, signal splitting does not cause problems on extended pairs 405, and connected telephone devices will also not have an influence on transmission over those pairs.

U.S. Patent No. 5,010,399 and Parts I and II of this disclosure describe many of the relationships between the properties of a signal and its tendency to be attenuated and distorted during transmission across telephone wiring. As described therein, the maximum transmission length increases with decreasing frequency because of improvements in transmission characteristics. Specifically, attenuation, radiation, and the ability of the wiring to pick up (interfering) broadcast energy all decrease as transmission frequency is reduced. Also, crossover of energy between neighboring pairs decreases with decreasing frequency. Those applications also discuss spectral tilt, another undesirable byproduct of transmission over telephone lines.

Part I of this disclosure explains that FM video signals have a greater noise immunity than do AM video signals, i.e., the SNR after demodulation of an FM signal is higher than that of AM video signals if the frequency modulation process creates a signal with a wider bandwidth than the AM signal. As explained in Part I of this disclosure, the sensitivity advantage of FM video signals

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over AM increases as the bandwidth of the FM signal increases.

The ability of FM signals to reject interference increases when the interfering signal is a second FM signal 5 confined within the same channel. As explained in Part I of this disclosure, the minimum energy advantage that a receiver requires to reject a weaker but otherwise equivalent signal in the same channel is known as the "capture ratio", and is often significantly less than the 10 minimum SNR necessary to avoid distortion by white noise. The exact capture ratio will depend on several factors, but the inventors estimate that the "capture ratio" of an FM NTSC video signal with a 15 Mhz wide bandwidth will typically be less than 10dB, allowing it to ignore 15 interfering FM signals whose levels are suppressed by at least 10dB.

Using FM to transmit video has three disadvantages, however. One is that the tuning circuitry of common television sets expects to receive AM signals. This means 20 that an extra signal conversion may be required before a picture is generated. Secondly, FM video electronic circuitry is more expensive. The third disadvantage is that a group of adjacent FM video channels will cover a wider band than a group of adjacent AM channels. In 25 addition to occupying more spectral area, a band of adjacent FM channels will reach higher frequencies than a band of the same number of adjacent AM channels (assuming that both bands begin at the same frequency). Signals transmitting over FM channels, therefore, will generally 30 suffer more from the problems associated with increasing frequency.

When processor 418 transmits several signals simultaneously across one of extended pairs 405, it assigns each signal to a separate frequency band, or channel. The 35 energy of each signal will be confined within that band.

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(Effectively, this "channelizes" that particular extended pair 405.) Additionally, processor 418 determines the waveform and energy level of each individual signal. On the basis of the considerations described above, a set of 5 guidelines have been developed to aid in determining these characteristics for a given communication scenario. Some of the guidelines apply to transmission of signals of a general nature. Other guidelines will apply only to television signals. Still others will apply only to the 10 specific situation of the communication of one or two video signals over especially long distances. These guidelines are disclosed in the following paragraphs (1-6).

1) Energy Level

Because RF signals that may be transmitted across 15 telephone lines are relatively low in power, increasing signal level is not likely to cause a significant increase in cost, and is also not likely to cause problems of safety. Furthermore, maximizing the signal levels maximizes the SNR at the receiver. Thus, there are no 20 benefits to lower signal levels, and the signal level should be set so that the resulting radiation falls just below governmental limits on the airborne radiation.

Because telephone wiring is unshielded, EMF radiation will result no matter how well the transmitting 25 or receiving devices are shielded. Thus, these radiation levels will not significantly vary with any factor other than the signal level. This means that the radiation can be determined at the time of manufacture, avoiding the expense of providing for adjustable signal levels.

30 For example, following FCC procedures, the inventors fed a 22.45 Mhz NTSC video signal onto a telephone wire and measured the resulting radiation. It was found that at a conducted signal level of approximately 50dB mV, radiation from the wire would be just below the governmental limits 35 of 30uV/M measured at 30 Meters. Thus, a level of 50dB mV

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would be preferred for a transmitter that applies a 22.45 Mhz video signal to telephone wiring.

2) Adjacent Low-Frequency Channels

As described above, attenuation, radiation, 5 crosstalk interference and reception of external interference all increase as frequency increases. This means that the signal with the highest frequency is most likely to have the lower SNR, and that overall communication success can be improved by lowering the 10 frequency below which all signals are confined.

To minimize the highest frequency used for transmission, it is recommended that the first channel be placed as close to the voiceband as feasible, and that each succeeding channel be placed above and adjacent to the 15 previous channel. The channels should be separated in frequency sufficiently, however, to allow clean separation at the receive end without excessive filtering costs.

3) Minimum Frequency

If AM is used to transmit video signals, it is 20 preferred that the picture carrier of the first such channel be located above 4.25 Mhz. This frequency is chosen as a rough compromise between the following factors: a) transmission properties improve with lower frequencies; b) as described in Part I of this disclosure, the 25 likelihood of distortion of AM signals caused by the phenomena of spectral tilt increases with decreasing picture carrier frequency below 5 Mhz; and c) there are certain advantages in arranging for transmission of several adjacent 6 Mhz AM NTSC video signals beginning with a 30 signal whose picture carrier is at 4.45 Mhz. (One major advantage, which is described more fully in Part II of this disclosure, is that arranging video channels in this manner reduces the likelihood of interference from amateur radios.)

35 For FM transmission, it is preferred that the low

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end of the first channel be 4 Mhz. This frequency is chosen as a rough compromise between the following considerations:

- 5 a) Transmission properties improve at lower frequencies;
- 10 b) Spectral tilt becomes more pronounced with increasing ratios between the highest and lowest frequencies of an FM signal. (the problem of the spectral tilt of FM signals is described in Part I of this disclosure);
- 15 c) lowering the low end of an FM band by 1 Mhz does not provide a significant decrease in the percentage reduction of the frequency of the high end. For example, moving the low end of a 15 Mhz channel from 3 Mhz to 2 Mhz only reduces the upper frequency by 5%, i.e. from 18 to 17 Mhz.

4) Bandwidth

Assume that "N" different signals are to be transmitted within adjacent channels, that the average width of the channel confining a signal is B Mhz, and that the low end of the lowest channel is k Mhz. Under these conditions, the high end of the channel highest in frequency is given by $(Nb + k)$ Mhz. Thus, decreasing bandwidth decreases the maximum frequency.

Because of this, a preferred system when transmitting multiple NTSC video signals is to provide all signals using AM modulation within 6 Mhz channels distributed according to the NTSC standard. (I.e. a picture carrier 1.25 Mhz above the low end and a sound carrier .25 Mhz below the high end.) This arrangement is chosen because the bandwidth is relatively narrow, yet separation can be achieved using inexpensive filtering. This is the same arrangement that was chosen for airwave transmission of video shortly after the invention of television. The same justifications applied. Because of that standard, very inexpensive electronics exist for this type of channeling, providing another advantage.

The preferred lower end for the band of transmission over extended pairs 405 is defined by an AM signal with a

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picture carrier of 4.45 Mhz. (The lower end of an NTSC video channel with a carrier of 4.45 is at 3.2 Mhz. This is because the bottom of the 6 Mhz channel is 1.25 Mhz below the picture carrier.) The advantages of providing 5 adjacent AM signals with picture carriers spaced 6 Mhz apart and beginning at 4.45 Mhz are described in Part II of this disclosure. Also, a picture carrier of 4.45 Mhz is above the minimum frequency requirement of 4.25 Mhz suggested above.

10 Amplitude modulation is particularly adequate when only a small number of signals transmit over a short distance. As transmission distance increases, attenuation causes the SNR at the receiving end to drop. Similarly, as more channels are added to a wire pair of fixed length, one 15 is forced to use higher frequencies, until the signal at the highest frequency is not received with an adequate SNR. (Note that capacity tightens up very rapidly with increasing frequencies because attenuation increases and at the same time the signals radiate more, forcing a reduction 20 in the initial signal levels.)

A third phenomenon that can cause an inadequate received SNR is the presence of broadcast energy, which elevates the noise level. This is largely a function of the radio broadcasters in the area, but it is also related to 25 frequency because telephone wiring acts as a more efficient antenna as the frequency of the broadcast signal increases.

5a) Increasing Bandwidth to Counter Signal Attenuation

When the attenuation of transmission or the presence 30 of broadcast energy at the "unused" frequencies on a transmission line suppresses the SNR at the receive end below the minimum required for AM video, the proposed solution is to use frequency modulation with bandwidths significantly larger than 4 Mhz. (Four Mhz is the 35 approximate bandwidth of an NTSC video signal at baseband.) As mentioned in Part I of this disclosure, receivers in FM

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communication systems that use 15 Mhz of bandwidth per NTSC video signal are known to produce a demodulated signal that is approximately 10db higher than the SNR at its input. This is an improvement over AM systems because, in those 5 systems, the SNR at the receiver output is equal to the SNR at the receiver input.

Following is an example. Assume that nine AM NTSC signals transmit across a path 400 feet long within adjacent 6 Mhz channels beginning at 6-12 Mhz and ending at 10 54-60 Mhz. Now assume that a signal of 45dB mV with a carrier at 61.25 Mhz, (corresponding to the channel between 60-66 Mhz), creates radiation just below the legal (FCC) limit when applied to telephone wiring. Because the attenuation on telephone wiring at 60 Mhz is approximately 15 12dB per 100 feet, the SNR of such a signal at the receive end of the above path should, theoretically, be -3 dB mV, or 3 dB below the minimum (0 dB mV) required for high quality video reception.

A solution is to transmit a 15 Mhz wide FM signal 20 between 60 Mhz and 75 Mhz. The high end of this signal, being at 75 Mhz rather than 66 Mhz, will suffer greater attenuation, and will also radiate more energy. According to measurements performed by the inventors, however, the radiation difference will be negligible, (perhaps 1 dB), 25 and the extra attenuation at 75 Mhz over the 400 foot path will be approximately 2 dB. Thus, the received level will be approximately -6 dB mV. If the SNR at the output of a 15 Mhz FM video receiver is approximately 10 dB higher than the SNR at the input, however, the SNR of the demodulated 30 video signal will be 4dB, which is sufficient. Thus, transmission of an extra channel can be enhanced by using FM for the additional channel.

At higher frequencies, the 10dB advantage of a 15 Mhz FM signal may not be sufficient to overcome the extra 35 attenuation. The solution, in that case, is to use wider

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FM bandwidths which produce a greater SNR improvement at the receiver. This, of course, brings one to even higher frequencies more quickly with each channel that is added. Because of this, the inventors expect that higher 5 frequencies will not be useful beyond some point, and certainly not beyond 1000 Mhz.

5b) Using FM to Counter Crosstalk

Within a bundle of unshielded telephone wire pairs, the amount of energy radiated by one pair that is received 10 by another increases with frequency. This happens both because the radiation at a fixed signal level increases with frequency, and because the ability of the second wire pair to "pick up" the radiation also increases. This energy received by the second wire pair is known as "crosstalk" 15 and the tendency of a particular medium to exhibit this type of interference is known as "crosstalk loss." That quantity is the ratio, in dB, between the signal directly applied to a communication line and the energy received from the radiation of a signal of equal strength fed to a 20 neighboring line. The greater the "crosstalk loss," the less the interference.

At the voiceband frequencies of ordinary telephone signals, which are below 5 KHz, crosstalk loss is very high. Thus, the portion of the "noise" typically 25 encountered by telephone signals that is related to crosstalk energy is very small. For this reason, telephone signals on neighboring wire pairs usually do not interfere with each other.

At frequencies above 1 Mhz, however, interference 30 from crosstalk can be significant. Crosstalk loss will be affected by many different factors. According to measurements, made by the inventors, of several bundles of 12 pair and 25 pair telephone wires, crosstalk loss at 6 Mhz occasionally becomes less than 45 dB, while crosstalk 35 loss above 50 Mhz rarely exceeds 40dB. These measurements

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indicate that AM video signals, which can display the effects of interference at SNRs as low as 40dB, may suffer interference from crosstalk at even relatively low frequencies such as 6MHz.

5 FM signals, on the other hand, have impressive resistance to crosstalk interference because of their very low "capture ratios." As stated in Part I of this disclosure, the inventors estimate that receivers that process FM video signals with bandwidths of 15 Mhz or more
10 can reject interference from any FM signals transmitting in the same channel if the level of the interfering signal is weaker by 10dB or more. Thus, it would appear that FM video signals will not encounter crosstalk interference until at least 50 Mhz, and the use of FM at the very lowest
15 video channel may be indicated.

5c) Using Secondary Pairs for Additional Channels

As mentioned above, there is an upper limit to the frequencies that can be useful for transmission of signals across a transmission path of a given length. Thus, the
20 number of signals that can transmit over an extended pair to a given local network is limited.

In most apartment buildings, however, several extended pairs service (i.e. are dedicated to) each apartment unit. Each of these pairs typically branches off
25 to connect to each of the jacks in the unit. Typically, one of these pairs conducts the signals for the primary telephone service to that unit. Additional pairs are left empty unless and until secondary telephone lines are requested. Thus, apartment units are typically serviced by
30 more than one of extended pairs 405 and, correspondingly, more than one of local networks 411.

An example is where red, green, black, and yellow conductors connect at each jack in a unit and also extend down to the point of concentration in the basement of the
35 building. The red and green wires in the unit constitute

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one of local networks 411, and the yellow and black wires constitute a second of local networks 411. The lengths of these wires that extend down to the basement of the apartment building constitute the extended pairs 405.

5 If more signals are required than can be accommodated by a single extended pair, the extra wires present an opportunity. As described earlier, the twisted pairs connecting to the same unit may be bundled more tightly together than arbitrary pairs in the same bundle,
10 potentially increasing crosstalk interference. If this increase is not dramatic, however, the techniques to avoid crosstalk described above will be sufficient to prevent crosstalk interference between signals on these two pairs that serve the same unit, preserving the opportunity for
15 transmission of additional signals.

Indeed, using an additional pair for the second channel provides the economy that fewer frequency bands are required to transmit a given number of signals. For example, assume that transmitting two signals can be done
20 by using FM within the channels between 6-18 Mhz and 18-30 Mhz, and that at most two signals are required by any unit. It may be more economical, in this case, to provide the second signal within the 6-18 Mhz channel but on a secondary pair. This allows video receivers 419 to receive
25 either signal using only the electronics necessary to tune the 6-18 Mhz channel. Switching from one signal to the other is simply a matter of switching between wire pairs.

Transceiver/switch 400 can enjoy a similar economy. Using the example above, transceiver/switch 400 need only
30 be equipped to transmit within the 6-18 Mhz channel to satisfy the system requirements.

5d) Transmitting over Unused VHF Channels

As described in Part I of this disclosure, systems that transmit signals at unused VHF television channels are
35 very reliable because they enjoy the advantage of total

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immunity (as a practical matter) from broadcast interference. It was further described how the relatively high attenuation suffered by signals transmitting at those relatively high frequencies can be overcome, in some 5 circumstances, by using low-pass filters to remove all of the attenuative affects of all telephone devices connected to the wiring.

Because cable TV companies consider reliability an extremely important part of their delivery systems, use of 10 unused VHF channels within the systems described herein is an interesting option. For example, a cable company considering distribution of AM signals through an apartment unit within 6 Mhz channels below 30 Mhz may be concerned that an amateur radio enthusiast can erect an antenna 15 nearby and broadcast at the 10 meter, 15 meter, 20 meter, and 30 meter bands, all of which are below 30 Mhz.

One of the problems of using unused television broadcast channels in the systems that are the subject of this application, however, is that the wires leading to the 20 various units may be bundled tightly together, causing the crosstalk problems described above. Crosstalk interference is even more likely to occur because crosstalk increases with frequency, and unused TV channels are at relatively high frequencies. Also, because adjacent unused channels 25 are not typical, only 6 Mhz is available per channel, preventing the use of FM, which is more resistant to crosstalk.

In many apartment buildings, however, the wires providing telephone signals to an individual unit are often 30 not bundled tightly together with wires leading to other units. This is especially common for the wires that lead from a "wiring closet" that serves as a concentration point for the various units on the same floor. Often, separate bundles of four or more conductors lead from this point to 35 each apartment unit. Because the bundles are separate,

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crosstalk will be negligible. Because they need not traverse between floors, moreover, these bundles are relatively short in length, decreasing the likelihood that they will exceed the relatively short transmission length
5 limits imposed by unused television channels.

The combination of short path lengths and separate bundles is an ideal configuration for transmitting over the unused television channels. Following is an example. Assume a five story apartment building in New York City
10 includes five units on each floor, and that four wires service each of the units on a floor. Assume further that the conductors from each unit are bundled together and lead to a wiring closet on the same floor. Inside each wiring closet, transceiver/switch 400 is installed and connected
15 to the cable TV trunk which is brought to each closet. (Leading this cable to each closet is the only wire installation required.) In New York City, VHF channels 2, 4, and 5 are used, making VHF channels 3 and 6 open for transmission. Using the technology described herein,
20 transceiver/switch 400 feeds two different signals, one at VHF channel 3 and one at VHF channel 6, onto one of the twisted pairs leading to each unit. Note that the second twisted pair will typically not be useful because it is bundled too closely to the first pair.
25

6) Transmission of Video using Compressed Digital Signals (Fig. 35)

Currently, extensive effort is focused on developing methods to compress digital representations of NTSC video signals. These efforts have reached the point where it
30 appears that the digital bitstream representing an NTSC video signal can be compressed sufficiently so that it can be transmitted within a channel narrower than the 4 Mhz occupied by the video portion of the original analog NTSC signal. In other words, the digital bitstream can be
35 expressed, using techniques such as pulse code modulation (PCM), as an analog signal with a bandwidth less than 4

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Mhz. Furthermore, the SNR required for accurate reception of this signal and recreation of the compressed bitstream is less, potentially, than the SNR required for quality reception of FM video signals. Also, the digital signal 5 has similar resistance to crosstalk interference. Thus, it appears that video signals can be communicated more efficiently across networks of the particular type discussed herein if they are in digital form. The drawback of digital transmission of video, of course, is the expense 10 of digitization and compression of the video signal at the transmit end, and the expense of the inverse processes at the receive end. Because it is expected that compression circuitry will dramatically decrease in price, techniques to transmit compressed digital video signals are included 15 in a later section of this disclosure and shown in Fig. 35.

D. Two-Way Transmission of Video Signals

The guidelines for choosing transmission bands and modulation methods for transmitting video signals from transceiver/switch 400 to local networks 411 also apply for 20 transmission in the opposite direction. An extra consideration arises, however, when transmission in both directions takes place simultaneously. The consideration is a form of interference sometimes called "nearend crosstalk." This interference can occur when signals are 25 fed to a wire pair at one end while signals transmitting at the same frequencies are received from a neighboring pair (in the same bundle) at the same end. To see why this type of situation is likely to cause interference, consider the following example.

30 Assume that transceiver/switch 400 modulates a first video signal using AM with a carrier frequency of 8 Mhz and feeds it onto extended pair 405a, and that local network interface 404b modulates a second video signal using AM and a carrier at the same frequency and feeds it onto extended 35 pair 405b towards transceiver/switch 400. Assume further

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that the attenuation of transmission at 8 Mhz is 2 dB per 100 feet, and the paths, i.e. pairs 405a and 405b, are 1000 feet long.

Now consider the signals present at 5 transceiver/switch 400 on pair 405b. The level of the first signal is simply that produced by transceiver/switch 400 minus the loss in energy as it leaks from pair 405a onto pair 405b. The level of the second signal, which is the signal of interest on 405b, is 20 dB lower than that 10 produced by interface 404b because of the attenuation of transmission. Thus, if the second signal is an AM video signal, interference will occur unless the first signal loses at least 60dB crossing from 405a to 405b. Experiments performed by the inventors indicate that, in 15 typical situations and at frequencies above 5 Mhz, the crossover loss is likely to be much less than that, perhaps even low enough to cause interference with FM video signals.

The solution proposed herein is to ensure that the 20 bands used for transmission in the "forward" direction, i.e. from transceiver/switch 400 to local networks 411, are the same for each of extended pairs 405. In other words, the frequencies used by signals transmitting along extended pair 405a from transceiver/switch 400 to local 25 network 411a are not also used by signals transmitting over extended pair 405b in the reverse direction, i.e. from local network 411b to transceiver/switch 400.

As described above, a very important application of the techniques disclosed herein is the one-way distribution 30 of cable TV signals. In these types of applications, wideband video signals are transmitted from transceiver/switch 400 (i.e., the point of convergence) to local networks 411, and control signals, which will be narrowband because they have very small information 35 content, transmit in the opposite direction to provide the

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selection mechanism.

In these situations, where only a very narrow (e.g. less than .5 Mhz) signal transmits towards transceiver/switch 400, it is preferred that the narrowband signal transmit just above voiceband, below the wideband signals. This reduces the expense of filtering, because the cost of a filter is inversely proportional to its "fractional bandwidth," which is the bandwidth divided by the center frequency. Thus, a .5 Mhz filter at 1 Mhz, for example, has a fractional bandwidth of .5, and the fractional bandwidth of a 6 Mhz video signal at 4 Mhz is 1.5. Reversing the frequency order of the narrowband signal and the video signal, i.e., placing the narrowband signal at 7 Mhz and the video signal at 3 Mhz, makes these fractional bandwidths .07 and 2, dramatically decreasing the fractional bandwidth of the narrowband signal, without significantly changing that of the video signal.

E. Transmitting a Single Video Signal over Long Transmission Lengths (Figs. 23A-23C)

When transmission lengths are longer than 1000 feet, transmission problems may be encountered even at frequencies below 10 Mhz. In these types of situations, use of extended pairs 405 to communicate multiple signals over a large frequency range may not be feasible. A system that communicates only a single video signal, however, can still be very useful in many important applications.

To provide for communication of a single video signal under circumstances of long transmission length, three different sets of specific waveform/frequency combinations are shown in Figs. 23a-23c and disclosed below. To gain extra transmission length, each of these uses frequencies below the lower limits suggested above.

Each of these techniques has advantages and disadvantages vis-a-vis the other two. One technique is to transmit the signal amplitude modulated at a frequency

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slightly above voiceband (Fig. 23a). A second technique is to transmit an unmodulated signal at baseband (Fig. 23b). The third technique is to transmit the signal frequency modulated within a band having a low end of approximately 5 3 Mhz (Fig. 23c).

One of the applications where communication of a single video signal can be important is in transmitting cable TV signals over extended pairs 405. In this case, provision is made for the user to select the signal to be 10 transmitted. Methods of encoding low data rate bitstreams, e.g., 100 bits per second, into signals with narrow bandwidths, e.g., less than .5 Mhz, that can tolerate very low SNR levels at the receiver input are well known. Thus, it will be appreciated that the "selection" (i.e., control) 15 signal can normally be transmitted at frequencies above the video signals in each of the techniques described below, and still tolerate the added attenuation of those higher frequencies.

Alternatively, in the case of the distributions 20 shown in Figs. 23a and 23c, there is "room" to transmit a narrow band control signal between the voiceband and the video signal. Because placing narrowband signals near the voiceband reduces filtering costs, as described above, this is a preferred method of transmitting these signals. Thus, 25 Figs. 23a and 23c allocate a small part of the spectrum between the voiceband and the video signal to these selection signals.

The distribution shown in Fig. 23b does not allow 30 this because the video signal extends down to baseband. In this situation, a preferred method is to transmit the narrowband "selection signal" in a frequency band above both the video information and the telephone signals.

1) Amplitude Modulation within a Low-Frequency Channel (Fig. 23a)

35 In the first technique, processor 418 converts each video signal selected from communication line 402 to an AM

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signal whose carrier frequency is below 3 Mhz, and is preferably closer to 1 Mhz. To prevent interference with telephone signals, the lower sideband of this signal, known as the lower vestigial sideband, is suppressed to 5 substantially eliminate the energy in the voiceband.

Fig. 23a shows the spectrum of such a signal. The carrier frequency is 1.25 Mhz, with the lower sideband substantially suppressed below 1 Mhz. The 1.25 Mhz frequency is chosen as a compromise between the 10 transmission advantages of lower frequencies (which are described in U.S. Patent No. 5,010,399 and Part I of this disclosure,) the disadvantages of lower frequencies (which are described below), and a particular advantage of the specific frequency of 1.25 Mhz (described in the next 15 paragraph).

One of the disadvantages of lower frequencies is that the filtering that separates these signals from voiceband signals is more expensive because of the sharp cutoff required between the upper end of the voiceband and 20 1 Mhz. A second disadvantage is that the harmonics of the telephone signals at lower frequencies are stronger, meaning that stronger filtering of the harmonics is required to protect against interference from these signals. A third disadvantage is that the modulation 25 electronics become more expensive as the picture carrier approaches DC. The particular advantage of the 1.25 Mhz picture carrier is that it coordinates with one of the channelization schemes disclosed in Part II of this disclosure.

30 In the channelization scheme shown in Fig. 23a, the audio component of the television signal is frequency modulated with a carrier frequency of 5.75 Mhz. That is, the audio component is placed slightly above the high-end of the video band. In particular, it is spaced 4.5 Mhz 35 above the video carrier, thus following the convention of

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standard NTSC channels.

The signals whose harmonics are likely to cause the interference described above are those with high energy, such as ringing signals, and signals relatively high in frequency such as the transient signals that occur with sudden voltage changes during hook-switching. Ordinarily, the harmonics as high as radio frequencies are harmless because the energy level of a harmonic series reduces with frequency. Because of the relatively low frequencies of the video signals, however, these harmonics may still have significant energy when reaching the same frequencies.

The ringing and transient signals originate at local exchange 476 or within telephone devices 414. To prevent this type of interference, these sources are filtered, preventing the harmonics from transmitting onto extended pairs 405. This filtering is now described.

Referring again to Fig. 22, filters 474, which include low-pass filters 474a-474e, respectively, placed in series on each of twisted pairs 476a-476e, block the harmonics of telephone signals that originate at local exchange 475 from transmission to extended pairs 405. This avoids interference with RF signals transmitting over those wires. Similarly, transients and harmonics created by the telephone devices 414 on local networks 411 are blocked from crossing over to extended pairs 405 by filtering within local network interfaces 404. That filtering is shown in Figs. 33a-33b and is described below. In the embodiments where local network interfaces 404 are not provided, other filtering must block the harmonics of telephone devices 414. This filtering is provided by the low pass filter (LPF) interposed between each of telephone devices 414 and the network wiring, as shown in Fig. 21a.

As described in Part I of this disclosure, the video signal shown in Fig. 23a may suffer from the problem of spectral tilt because it is amplitude modulated with a

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picture carrier substantially below 5 Mhz. To reduce this tilt, processor 418 pre-emphasizes, or amplifies, the higher frequencies of the signal by a greater amount than the lower frequencies. This pre-emphasis is performed in 5 processor 418 by modulators 410a-410d (collectively, modulators 410) as described below.

If pre-emphasis is not provided, or if the signal arrives at the corresponding local network interface 404 with a significant tilt despite precautions, processing in 10 interface 404 can include means known as equalization that estimate the tilt and adjust the spectrum accordingly. Alternatively, equalization can be performed in video receivers 419 that recover signals from local networks 411 and provide them to televisions 492.

15 In the reverse direction, compensation for spectral tilt is implemented by providing pre-emphasis in video transmitters 417 or in local interfaces 404. Alternatively, equalization of the video signals received from extended pairs 405 can be provided in demodulators 416 20 of processor 418, as described below.

The preferred compensation technique for the spectral tilt of signals transmitting to local networks 411 is to perform pre-emphasis in processor 418. The preferred technique for compensation of signals transmitting in the 25 opposite direction is to use equalization in processor 418. These techniques are preferred because using them would confine all the special compensation circuitry in a single device, transceiver/switch 400, which would seem to be economical. Also, adjustment of the compensation circuitry 30 must normally be done for each of extended pairs 411. Thus, performing an adjustment for an entire system is more convenient when the adjustment controls are confined to one device.

35 2) Transmitting Unmodulated Video Signals over Active Twisted Pairs (Fig. 23b)

Referring to Fig. 23b, an alternative to

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transmission using AM at a low frequency is to transmit the video signal in its unmodulated form. This will reduce (e.g., by 25%) the highest frequency used by the video signal below that of the previous example from 5.25 Mhz to 5 4 Mhz, reducing the attenuation of transmission and providing a further increase in the length over which transmission can succeed. Equally important, crosstalk energy from neighboring pairs will also decrease.

Because the unmodulated video signal occupies 10 voiceband frequencies, telephone signals on extended pairs 405 are transmitted within a frequency band above the unmodulated video signal to prevent interference. As shown in Figs. 29b and 33b and described below, signal separators 413 (Fig. 29) and local network interfaces 404 (Fig. 30) 15 cooperate to ensure that the telephone signals transmit above 4 Mhz on pairs 405. Fig. 23b shows the .5 Mhz band centered at 5.0 Mhz allocated to telephone signals.

Transmission of a television signal also requires, of course, transmission of audio information. As shown in 20 Fig. 23b, the audio information transmits FM encoded at 4.5 Mhz, just above the end of the video spectrum. This is consistent with the NTSC standard. Control signals for channel selection are transmitted within a .5 Mhz band centered at 5.5 Mhz.

25 Provision of the telephone, control, and audio signals above the video band would seem to defeat the advantage of using unmodulated signals to reduce the maximum frequency. Because the information content of the audio and telephone signals are very low, however, these 30 signals can be FM encoded so that the minimum SNR that they require at the receiver is much less than the 40dB required by an AM video signal. This means that the transmission length is limited by the attenuation at the upper bound (4 Mhz, in this case) of the video signal, and that distortion 35 from crosstalk interference will be caused by crosstalk at

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4 Mhz before it is caused at the frequencies used by the audio and the telephone signals.

To transmit unmodulated signals, processor 418 receives signals from communication line 402 and 5 demodulates them, if necessary. Processor 418 then amplifies these signals, and switches a separate signal on each one of paths 478 leading to signal separators 413.

Under the proposed scheme, telephone signals from local exchange 475 that transmit over twisted pairs 476 at 10 voiceband frequencies are converted to RF frequencies (FM, with a 5.0 Mhz carrier frequency) by signal separators 413 and fed onto extended pairs 405. Electronics within local network interfaces 404 convert the RF telephone signals back to baseband and the video signals to an RF frequency, 15 and feed both onto local networks 411. This allows the telephone signals to be received from local networks 411 by telephone devices 414 in the ordinary manner. (Because they are at baseband, the telephone signals will pass through the low pass filter (LPF) connected between each of devices 20 414 and the local network wiring.)

In the opposite direction, telephone signals are fed to local networks 411 by telephone devices 414. These are intercepted by local network interfaces 404, converted to RF signals, and fed onto pairs 405 towards 25 transmitter/switch 400. These signals are received by signal separators 413, converted to ordinary voiceband telephone signals, and fed (via filters 474) onto pairs 476 leading to local exchange 475.

Some of the details of the telephone signal 30 processing are shown in Figs. 29b and 33b and are described in detail below. Note that local network interfaces 404 are needed to implement this scheme.

Because energy at the frequencies near DC will be attenuated much less than energy at 4 Mhz, the spectrum of 35 the video signal is likely to tilt significantly during

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transmission over extended pairs 405. The same pre-emphasis and equalization techniques described to compensate for the tilt of low-frequency AM signals can be used to adjust these baseband signals, and reduce the possibility of distortion.

3) Frequency Modulation within a Low-Frequency Channel (Fig. 23c)

In this technique, processor 418 converts each signal derived from communication line 402 to an FM waveform before transmitting the signal onto the selected one of extended pairs 405. It is preferred that the video energy be distributed between 3 Mhz and 18 Mhz, as shown in Fig. 23c. A 15 Mhz bandwidth is preferred partly because this range is sufficiently wide to ensure that the minimum SNR required at the receiver input is significantly lower SNR than that required by an AM video signal. FM transmission also provides extra protection from crosstalk interference. These benefits can justify the added expense of FM modulation in certain situations.

20 When extended pairs 405 are particularly long, of course, the SNR at the receiver input will be below that required by 15 Mhz FM signals. In this event, bandwidths wider than 15 Mhz can be useful because they will provide extra sensitivity, i.e., their minimum SNR level will be
25 even lower. They do, however, suffer greater attenuation because they have energy at higher frequencies. If the greater attenuation does not defeat the extra sensitivity, bandwidths wider than 15 Mhz can extend the transmission length.

30 The 3-18 Mhz band is preferred above 15 Mhz bands lower in frequency because the advantage of lower bands is small. The attenuation difference, for example, between 16 and 18 Mhz is approximately .5dB per 100 ft, meaning that only a very small advantage can be realized by shifting the
35 low end of the 15 Mhz band from 3 Mhz to 1 Mhz. The advantage of the 3-18 Mhz band over a lower band of equal

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width is a reduction in expense of electronics, a reduced likelihood of interference from voiceband transients, and less spectral tilt.

As shown in Fig. 23C, the audio is frequency modulated to a frequency of 20 Mhz. This frequency was chosen because it is relatively close to the high end of the video band, yet not so close to the video that sharp filtering would be required. Other frequencies, however, can also be used.

Because it requires less SNR at the receiver input, video signals encoded using FM between 3-18 Mhz (Fig. 23C) can communicate over longer distances, under some circumstances, than can be achieved using AM with a carrier below 5 Mhz (Fig. 23A). Under other circumstances, the higher frequencies required by the FM signal will more than cancel this benefit.

Following is an illustrative example. At 18 Mhz, telephone wiring attenuates a signal approximately 3.5 dB per 100 feet. That means that the energy at the high end of the FM signal will be 10.5 dB lower after being transmitted 300 feet over an extended pair 405. The attenuation of energy at 4.5 Mhz, which is near the high end of the AM signal (Fig. 23A) or the unmodulated signal (Fig. 23B) is approximately 3 dB over the same path (i.e., 1 dB per 100 feet). Thus, after 300 feet, the level of the FM signal of Fig. 23C will be 7.5 dB lower than either of the signals of Figs. 23a or 23b.

Because of its higher sensitivity, however, the level of the FM signal need only exceed the noise by 30 dB, while AM and unmodulated signals should have an SNR of at least 40 dB. Thus, when first fed to the transmission line, the AM signal will 10 dB closer to its minimum required level, which is approximately 0dB mV for most receivers. Assuming the signals are fed at 30 dB mV, the high end of the FM signal will be at 19.5 dB mV after 300

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feet, while the high end of the AM signal will be at 27 dB mV. Thus, FM will still have an advantage, meaning it can tolerate, for example, more broadcast interference. The advantage, however, has reduced to 2.5 dB, i.e. the 5 advantage of 10 dB has been eroded by an amount of 7.5 dB. This advantage will disappear at a transmission distance of 400 feet.

Now consider the situation where local network interfaces 404 are not provided and the transmission path 10 includes 200 feet on extended pairs 405 and 100 feet on the part of the local networks 411 that leads to video receivers 419. In this situation, the attenuation of transmission will be the same but splits may be encountered along the final 100 feet (i.e., the portion of the 15 transmission path that includes a local network 411). Because each split causes 3.5 dB of attenuation, if 8 splits are encountered, the FM signal will be at -8.5 dB mV, above its requirement of -10 dB mV, while the AM signal will be at -1 dB mV, below its minimum.

20 Independent of the transmission path length, the FM signals will be more resistant to crosstalk interference than AM video signals. At 15 Mhz, for example, the crosstalk loss within a 25-pair bundle of wires varies between 25-50 dB, according to measurements made by the 25 inventors. (As explained above, crosstalk loss is the energy loss, in dB, suffered by a signal while broadcasting across to neighboring wires.) Thus, if signals transmit over ten neighboring pairs at similar levels, the interfering energy contributed by each pair will be 25-50 30 less than the signal of interest, and the total interfering energy will be 10dB higher, or 15-40 dB less than the signal of interest. (This assumes that the interfering signals are incoherent because they originate from different sources. The final paragraphs of this section 35 discuss the situation where the

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interfering signals are all the same, i.e., coherent.) FM video signals with a 15 Mhz bandwidth, however, can have a capture ratio of approximately 10dB, eliminating crosstalk as a problem in nearly all cases.

5 At 5 Mhz, on the other hand, which is the approximate upper frequency of the AM signals (Fig. 23A), crosstalk loss varies between 30-60 dB. Because AM signals require at least 40 dB SNR, there is a good possibility that this energy will cause interference with the AM
10 signals at that frequency.

4) Coherent Addition of Crosstalk Energy from Identical Signals Transmitting over Several Pairs at Once

A particular type of crosstalk interference can
15 occur when transmitting signals over several twisted pairs in a large bundle of pairs. Specifically, if the signals transmitting over a large group of pairs in a bundle are identical, and one particular pair outside that group carries a different signal, then the energy in the multiple
20 pairs may "add coherently" onto the single pair, causing more interference than would occur if all pairs carried different signals. Such a situation is likely to occur when a group of signals is made freely available for selection by users at several local networks served by the
25 same bundle. (i.e., when the signals on communication line 402 are not targeted specifically for one of the units.) In that event, this problem can occur when the popularity of one signal dominates the others.

An example is where a coaxial cable is brought to
30 the basement of an apartment building, and transceiver/switch 400 derives signals from that cable, offering any one of 30 video signals to the units therein by transmission over the telephone wires that lead to the units. Assume there are 25 units in the building, and 10
35 of those units select a first video signal. An eleventh unit selects a second video signal. Assuming crossover

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loss from any of the ten pairs to the eleventh pair is 30 dB, and the contributions from the ten pairs add coherently, the total amount of interfering energy on the extended pair carrying the second signal will be only 10dB 5 below the level of that second signal, or 20 dB higher than the interference from any one of the ten pairs carrying the first signal. Thus, even if FM is used, there is a high likelihood of interference with the second signal in this situation. (If the signals added incoherently, i.e., if 10 all units in the group of ten selected different signals, the total interfering energy would be 20dB below the signal of interest.)

Below we describe a technique which can reduce the increase in crosstalk interference which occurs in this 15 situation. This technique is embodied in signal separators 413 and shown in Figs. 29a and 29b.

F. Signal Processing, Conversion, and Switching in Transceiver/Switch 400 (Figs. 24-27)

As described above, conversion and switching of 20 signals in transceiver/switch 400 is accomplished by interface processor 418 (Fig. 24) and control signal processor 420 (Fig. 27). Processor 418 serves as the interface between transceiver/switch 400 and communication line 402, and also as the interface between different ones 25 of extended pairs 405. Each of signal separators 413 serves as the interface between transceiver/switch 400 and an associated one of extended pairs 405. As such, one of the functions of processor 418 is to select and recover video and other types of signals from communication line 30 402, change the characteristics of the recovered signals through processing, and apply them to signal separators 413 for transmission to local networks 411 via extended pairs 405. Another function of processor 418 is to receive video and other types of signals from signal separators 413, 35 process those signals, and transmit them to communication line 402. A third function of processor 418 is to apply

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signals received from one of signal separators 413 to a different one of signal separators 413.

As emphasized earlier, no processing (such as modulation, demodulation, or frequency shifting) of the signals destined for one of local networks 411 takes place after output from processor 418 (along paths 478) and before reaching local network interfaces 404. Thus, the signal processing performed by processor 418 on the individual signals it selects and recovers from communication line 402 determines the waveform, frequency, and amplitude at which these individual signals will be transmitted across extended pairs 405. This processing is discussed below.

Control signal processor 420 receives control signals transmitted onto local networks 411 (by IR control devices 493) that are targeted for master controller 415, and it also receives control signals from communication line 402. As described above, processor 420 converts the control signals to a form that can be interpreted by master controller 415, and then passes the resulting signals to controller 415. Master controller 415 uses those signals to determine, among other things, which signals shall be selected from communication line 402, and which of local networks 411 shall be targeted to receive those signals.

This processing is described in detail below.

A detailed description of a preferred embodiment of interface 418 is given in the following paragraphs, followed by a description of a preferred embodiment of control signal processor 420. It will be appreciated, however, that processor 418 can take on many different embodiments, as long as it fulfills the following three functions (which are also described above):

1) recover video and other signals from communication line 402, and transmit separate electrical signals, including combinations of the recovered signals, onto each of paths 478 that lead to signal separators 413;

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- 2) receive signals transmitted from signal separators 413 along paths 479, process these signals, and apply them to communication line 402;
- 5 3) receive signals transmitted from signal separators 413 along paths 479, process these signals, and apply them to other signal separators 413.

There are many ways that processor 418 can be implemented to fulfill these functions. Indeed, the closed 10 circuit TV industry provides a large variety of electrical and optical processing devices that couple video signals, split video signals, modulate and demodulate signals, and shift signals in frequency. What is shown herein is a method that is preferred in this application, as well as 15 several alternatives.

1) Processor 418 (Fig. 24)

Referring to Fig. 24, processor 418 includes interface 409, signal distribution subsystem 403, and signal collection subsystem 407. Interface 409 performs 20 two functions. One is to receive signals from communication line 402 and feed them to subsystem 403 in electrical form, independent of the form at which these signals transmit across line 402. (Thus, interface 409 can receive optical signals from communication line 402.) The 25 other function is to receive electrical signals from signal collection subsystem 407 and to apply them to communication line 402, independent of the mode (i.e. electrical, optical, or other) of line 402. (That is, if line 402 is a fiber optic medium, interface 409 converts electrical 30 signals from sub-system 407 to light signals.)

There are many examples of devices that perform such a function. Some of these are designed to interface between an optical line and an electrical communication system. One embodiment of interface 409 is shown in Fig. 35 24a, and is an example of an interface between a coaxial communication line 402 and an electrical system. It includes circulator 421, block converter 423, and block

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converter 447.

Circulator 421 receives energy from line 402 and transmits it to block converter 423 while isolating the received energy from block converter 447. Circulator 421 5 also receives signals from block converter 447 and applies them to communication line 402 while isolating block converter 423 from these signals.

Block converter 423 selects a particular frequency band from its input signal and shifts it in frequency, 10 transmitting the result to signal distribution subsystem 403. This is done in two steps. First, all input signals are heterodyned 423a, 423b to shift the selected band to the output band. Then, the shifted signal is transmitted through the output filter 423c and passed to subsystem 403. 15 As described later on, subsystem 403 transmits the signals received from interface 409 to signal separators 413.

Following is an example. Video signals between the frequencies of 54 Mhz and 900 Mhz transmit from line 402 through circulator 421 to block converter 423. Converter 20 423 performs a fixed downshift using a preset heterodyne frequency of local oscillator (L.O.) 423b of 620 Mhz, shifting the band between 650-700 MHz to the band between 30-80 Mhz. The result is passed through a filter 423c that only passes energy between 30-80 Mhz. Thus the frequency 25 band between 650-700 MHz is selected and converted to the band between 30-80 Mhz. All other frequencies in the 54 MHz to 900 MHz band are rejected.

Selection and conversion of a frequency band from communication line 402 in the manner described above can be 30 useful when certain frequency bands on a high capacity line are "reserved" for communication with a group of networks. Using the example above, communication line 402 can serve a neighborhood with includes many residences, with the frequencies between 650-700 being dedicated to 35 communication with the residences corresponding to the five

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local networks 411.

Interface 409 also receives a signal from signal collection subsystem 407. This electrical signal, which may include several individual signals combined together, 5 transmits to block converter 447. The frequency shifter 447a, L.O. 447b, and band pass filter 447c in block converter 447 combine to shift this signal to the frequency at which it will transmit across line 402, and amplifier 447d amplifies the result. Finally, block converter 447 10 transmits this signal through circulator 421 and onto communication line 402.

Following is an example. Video transmitter 417b receives a signal from video camera 494b (Fig. 21a), converts it to a single 20 Mhz FM video signal between the 15 frequencies of 20-40 Mhz, and transmits it onto local network 411b. This signal is amplified by local network interface 404b and transmitted across extended pair 405b. At transceiver/switch 400, the signal transmits to signal separator 413b (Fig. 22). That component directs the 20 signal to signal collection subsystem 407. Video transmitter 417c feeds a second video signal across extended pair 405c to subsystem 407 using a similar process. Using techniques described below, subsystem 407 converts these two signals to AM video signals within 25 adjacent 6 Mhz channels between 120-132 Mhz. These signals are transmitted over the same conductive path to block converter 447, which upshifts them to the band between 1000-1012 Mhz, and transmits them through circulator 421 to communication line 402.

30 Signal distribution subsystem 403 receives the electrical signals from block converter 423 and, under control of master controller 415 (via links 446a-446c), selects some of the individual signals contained therein. Subsystem 403 then creates several different combinations 35 of the selected signals. Specifically, a different group

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of selected signals is combined and applied to each of the conductive paths 478. Furthermore, each selected signal is converted to the frequency, waveform, and amplitude at which it will transmit across one of extended pairs 405.

5 (This conversion also assures that the selected signals in each group do not overlap in frequency.) These signals transmit to each of signal separators 413. (As described above, there is a one-to-one correspondence between signal separators 413 and paths 478.) Several embodiments of this

10 selection and combination process are described below. Examples of the signal processing of subsystem 403 will be given following these descriptions.

Signal separators 413 transmit the signals received from signal distribution subsystem 403 onto the corresponding one of extended pairs 405. Thus, interface 409 and distribution subsystem 403 cooperate to determine which signals transmit from communication line 402 to local networks 411.

In addition to selecting and distributing signals, signal distribution subsystem 403 also splits the signal received from interface 409, providing that signal to control signal processor 420 over path 420b. This allows processor 420 to detect signals from communication line 402 that are intended to communicate with master controller 25 415. As will be described below, processor 420 selects specific signals from path 420b by demodulating the energy within a specific frequency band. It then processes the resulting signal, and feeds it to master controller 415.

Except for control signals that provide communication with master controller 415, subsystem 407 receives all non-telephone signals that signal separators 413 receive from extended pairs 405. (Non-telephone signals are those not intended to communicate with local exchange 475.) These signals transmit from signal separators 413 to subsystem 35 407 along paths 479. Subsystem 407 selects

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particular signals from among those arriving on paths 479 and combines them onto a single conductive path. (Before combination, signals may be shifted in frequency to prevent them from overlapping in frequency and to arrange them 5 within adjacent channels for application to communication line 402.) This combined signal is transmitted to interface 409, as described above.

A detailed description of several embodiments of signal distribution subsystem 403 and signal collection 10 subsystem 407 is presented next.

2) Signal Distribution Subsystem 403a (Fig. 25a)

Signal distribution subsystem 403a, one preferred embodiment of signal distribution subsystem 403, is shown in Fig. 25a. As described above, interface 409 transmits 15 signals along a single conductive path leading to signal distribution subsystem 403a. Internal to subsystem 403a, these signals transmit to splitter 426', which splits the signal energy along several conductive paths. Four paths are contemplated in Fig. 25a. Three paths lead to 20 demodulators 426a-426c, (collectively, demodulators 426). The fourth path, labelled path 420b, leads to signal processor 420.

Processing of the output of splitter 426' by demodulators 426 is described in the following paragraphs. 25 Processing of this output by control signal processor 420 is described further on in this disclosure.

Each demodulator 426 (details are shown for demodulator 426c only) selects one signal from among those applied by block converter 423, and converts that signal to 30 baseband. The selection and conversion process conducted by demodulators 426 is similar to that performed by ordinary cable converters that have baseband outputs. As shown in Fig. 25a, the input signal is frequency shifted by multiplication with the output frequency of a local 35 oscillator. (A local oscillator is denoted by "l.o." in

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the figures of this disclosure.) The local oscillator frequency is tuned to bring the selected signal to an intermediate channel. The shifted signal is then filtered, isolating the intermediate channel. Finally, this signal 5 is demodulated, generating the selected signal at baseband.

The identity of the signal selected by demodulators 426 is determined by master controller 415. That component implements its control by sending signals along link 446a to each of demodulators 426. These signals determine the 10 frequency of the local oscillators of those components, thus determining which signals are brought to the intermediate channel by each demodulator 426. Ordinary techniques that achieve digital communication between two components on an electronic circuit board can suffice for 15 link 446a.

Under an alternative embodiment, the selection of an individual signal from communication line 402 is predetermined by the hardware instead of falling under the control of master controller 415. This can be done simply 20 by designing or manually adjusting demodulators 426 to demodulate only signals within a specific channel. Selection is then determined at the "headend" by feeding the desired signal onto line 402 at the channels to which demodulators 426 are tuned. For example, assume that 25 communication line 402 is a cable TV feed and that 100 NTSC video signals pass through circulator 421 to block converter 423 in interface 409a. Assume further that block converter 423 selects the 10 adjacent signals beginning at 300 Mhz and converts them to the 10 adjacent 6 Mhz bands 30 between 108 Mhz and 168 Mhz. Now let demodulator 426a be designed to always select the video signal expressed between 108 and 114 Mhz, whatever that signal may be. In this situation, the identity of the signal selected by demodulator 426a is determined at the "headend," or root of 35 the cable TV feed. Specifically, whatever signal is fed

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between 300-306 Mhz at the root will be selected and provided as output by demodulator 426a.

The basebanded signals output by demodulators 426 constitute the signals "selected" for distribution to local networks 411. (They are labelled the "selected" signals in Fig. 25a.) They will pass through separators 413 to extended pairs 405. First, however, they are converted to the waveform, frequency, and energy level at which they will be transmitted across extended pairs 405. This is accomplished by modulators 410a-410d (collectively, 410).

Each modulator 410 (the details of modulator 410d are shown) is designed or manually adjusted so that it always modulates its input in the same manner, outputting it within the same frequency band and at the same energy level. Thus, each of modulators 410 corresponds to a different "channel" used by signals that transmit across extended pairs 405. To provide flexibility in assigning any one of the signals selected by demodulators 426 to any of the channels created by modulators 410, signals from demodulators 426 transmit to modulators 410 through switch 462a. Thus, switch 462a assigns the selected signals to different channels.

Switch 462a works as follows. Internal to switch 462a are splitters 435a-435c (collectively, splitters 435), which have a one-to-one correspondence with demodulators 426. As shown in Fig. 25a, each of the signals from demodulators 426 transmits to splitters 435 which splits the energy of the signals onto four paths, each one leading to a different one of switching banks 448a-448d (collectively, banks 448). Each bank 448 responds to signals sent from master controller 415 along link 446b. In response to these signals any one of banks 448 can switch any one of its inputs to any or all of modulators 410a-410d. Thus, switch 462a can provide each of modulators 410 with the outputs of any demodulator 426.

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Because the outputs of demodulators 426 are all at baseband, however, master controller 415 ensures that at most one signal (i.e., the output of only one demodulator 426) is provided to any one of modulators 410 at one time.

5 Some of modulators 410, however, may not receive signals.

As described above, each modulator 410 converts the baseband signal it receives to a particular waveform, frequency, and energy level. The signals output by modulators 410 do not undergo further processing 10 (modulation or frequency shifting) before exiting subsystem 403. As described earlier, the waveform, frequency, and energy level of signals output by subsystem 403a is very important because these signals ultimately transmit to extended pairs 405 without any further processing except 15 for filtering and switching. Thus, the processing applied by modulators 410 determine, to a large extent, the reliability of transmission to local networks 411.

As described in Part I of this disclosure, when AM signals are transmitted with a picture carrier below 5 Mhz, 20 spectral tilt is likely to cause distortion. One of the proposed solutions is to "pre-emphasize" the high frequencies of the signal so that the attenuation related to transmission will result in reception of a signal with a flat spectrum. It is preferred that this pre-emphasis be 25 performed within modulators 410. Following is an example of how pre-emphasis can be implemented within modulator 410a.

Assume that modulator 410a outputs an AM NTSC video signal with a picture carrier at 1.25 Mhz (Fig. 23a). The 30 upper sideband of such a signal will extend approximately between 1.25 Mhz and 5.25 Mhz. Assume that attenuation of extended pair 405b at 1.25 Mhz is 1 dB per 100 feet, and at 5.25 Mhz it is 3 dB per 100 feet. (Assume further that the affect of attenuation follows, to a good approximation, a 35 linear variation between those endpoints.) If extended

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pair 405b is 1000 feet long, and the signal from modulator 410a is to be applied to pair 405b, the energy at 5.25 Mhz would ordinarily be received at a level 20 dB lower than that at 1.25 Mhz. To compensate for this, processor 410a 5 can include circuitry to "pre-emphasize" the signal such that energy at 5.25 Mhz is transmitted 20dB higher than that at 1.25 Mhz, and such that the pre-emphasis varies approximately linearly between those frequencies. Such pre-emphasis circuitry is known.

10 It is preferred that the modulation process follow any pre-emphasis process. This sequence is shown in the block diagram of modulator 410d (Fig. 25a). If AM waveforms are used, the modulation process involves mixing or multiplying the frequency of the signal by a local 15 oscillator. If FM waveforms are used, the modulation process involves "encoding" voltage variations of the signal as frequency deviations of the carrier. After modulation, the signal is filtered and amplified to the level at which it will transmit across the wiring.

20 Each signal produced by modulators 410 transmits through switch 401 over one or more of paths 478 to signal separators 413. (Paths 478 have a one-to-one correspondence with signal separators 413, and thus with extended pairs 405 and local networks 411.) Switch 401, which responds to 25 commands from master controller 415 sent over link 446c, is implemented in the same manner as switch 462a. Master controller 415, however, allows switch 401 to apply the output of more than one modulator 410 onto any one of paths 478a-478c. Thus, switch 401 "composes" the signal sent to 30 each of signal separators 413 by combining the outputs of modulators 410. The only restriction is that the signals from two of modulators 410 that overlap in frequency cannot be switched onto the same one of paths 478. The signals output by switch 401 are labelled "distributed signals" in 35 Fig. 25a.

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3) Signal Collection Subsystem 407a (Fig. 26a)

Signal collection subsystem 407a, one preferred embodiment of signal collection subsystem 407, is shown in Fig. 26a. Signals received by subsystem 407a arrive along 5 paths 479 and transmit to amplifiers 408a-408c (collectively, amplifiers 408). These signals originate on local networks 411.

Following is an example of the transmission path followed by a signal received by subsystem 407a. Signals 10 fed by video transmitter 417b to local network 411b are received by local network interface 404b and retransmitted onto extended pair 405b. These signals transmit across pair 405b to signal separator 413b. As is described later 15 on, signal separator 413b separates out the telephone signals and passes the remaining signals to amplifier 408b. Equivalent paths are used by other RF transmission devices to send signals to amplifiers 408a and 408c.

The output of each amplifier 408 passes through switch 429 to demodulators 416a-416d (collectively, 20 demodulators 416). Amplifiers 408 are provided to compensate for the energy loss caused by signal splitting internal to switch 429.

The design of switch 429 follows that of switch 462a in Fig. 25a. As such, switch 429 responds to commands from 25 master controller 415. These signals are sent over link 446d.

Each demodulator 416 selects a channel (i.e. a frequency band) from its input signal and converts the energy in that band to baseband frequencies. As shown for 30 demodulator 416a, the demodulation procedure involves frequency shifting a selected frequency band to an intermediate band, filtering that band, and demodulating the result. Equalization of the signal to compensate for spectral tilt is also performed, if necessary. In the case 35 of AM signals, it is preferred that the equalization be

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done after demodulation. In the case of FM signals, equalization should be done before demodulation but after filtering. The purpose of equalizing FM signals before demodulation is described in Part I of this disclosure.

5 (This equalization process is not to be confused with the process called "emphasis" which is part of standard FM communication. In this process, the level of the higher frequencies of the information signal are amplified before modulation, and then attenuated after demodulation. This 10 compensates for the tendency, inherently part of FM communication, whereby noise affects the higher frequencies of a signal more than the lower frequencies.)

The demodulation process creates a basebanded version of the signal in the selected band. Selection of 15 channels by demodulators 416 is done by altering the frequency of the local oscillator (l.o.) used to implement frequency shifting. This frequency is set in response to control signals from master controller 415 transmitted over link 446e.

20 The output of each demodulator 416 constitutes the signals "collected" from local networks 411. These signals are passed to modulators 428a-428d (collectively, modulators 428), which have a one-to-one correspondence with demodulators 416. As is described below, modulators 25 428 perform the first step in "exporting" signals by applying them to communication line 402.

As is also described below, in embodiments in which local networks 411 transmit video signals to each other, signal distribution subsystem 403b (Fig. 25b) is used in 30 place of subsystem 403a, and the "collected" signals are passed along paths 488a-488d (collectively, paths 488) to signal distribution subsystem 403b. Subsystem 403b can transmit each signal received from paths 488 to a local network 411 that is different from the local network that 35 originated the signal.

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By controlling switch 429 and demodulators 416, master controller 415 determines which of the signals input to amplifiers 408 are "collected," i.e. output from one of demodulators 416. Note that switch 429, because it follows 5 the design of switch 462a, can simultaneously connect the output of every amplifier 408 to any number of demodulators 416. This is important if the signal provided by one of amplifiers 408 includes more than one independent signal. For example, if the energy output by amplifier 408b 10 includes two adjacent 6Mhz NTSC video signals between 6-18 Mhz, and the output of amplifier 408b can be switched to both demodulators 416b and 416c, both video signals can be "collected." Note that none of demodulators 416 can receive the output of more than one of amplifiers 408, even 15 if the two output signals do not overlap in frequency. Such switching would not make sense because demodulators 416 select only one signal at a time.

As described earlier, modulators 428 implement the first step in applying the outputs of demodulators 416 to 20 communication line 402. Specifically, each of modulators 428 receives the single basebanded signal output by the corresponding one of demodulators 416. As shown in Fig. 26a, the process includes mixing the frequency of a local oscillator (l.o.) with that of the input signal, and 25 filtering the output. This process creates a new signal, with identical information content, within an RF frequency band.

The local oscillators used by each of the modulators 428 are such that the resulting output frequency bands do 30 not overlap. This allows the outputs to be combined onto a single conductive path. In a preferred embodiment, the frequency bands confining the outputs of modulators 428 are adjacent in addition to being non-overlapping. This minimizes the width of the band occupied by the combined 35 signal.

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The signals output by modulators 428 are all transmitted to coupler 428'. That component combines the individual signals onto a single conductive path, and passes it to interface 409. That component applies the 5 combined signal onto communication line 402, as described above.

4) Control Signal Processing (Fig. 27)

Referring to Figure 27, processor 420 includes filters 427a-427c and 427z (collectively, filters 427), 10 demodulators 443a-443c and 443z (collectively, demodulators 443), and digitizer 436.

As described above, control signals generated by individual control devices 493 and targeted for master controller 415 are transmitted onto local networks 411 by 15 video receivers 419, received by interfaces 404, and fed to extended pairs 405. The control signals are recovered from extended pairs 405 by signal separators 413 and routed to control signal processor 420 along paths 477, which have a one-to-one correspondence with signal separators 413. The 20 control signals arrive at processor 420 at the frequency and waveform at which they were fed to extended pairs 405.

Control signals from communication line 402 also transmit to processor 420. These signals are transmitted from signal distribution system 403 along path 420b (Fig. 25 24).

As seen in Fig. 26, path 420b connects to filter 427z, while signals transmitting over paths 477 present at corresponding filters 427a-427c. Filters 427 restrict the frequency of the signals passing to the corresponding 30 demodulators 443 to the bands used by the control signals targeted for master controller 415. Signals passing through filter 427z are received by demodulator 443z, while signals passing through filters 427a-427c are received by demodulators 443a-443c.

35 Demodulators 443a-443c and 443z convert such

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received signals to baseband frequencies, and pass the results to digitizer 436. That device converts the basebanded signals to digital signals, and passes them to master controller 415 over path 420a. Common methods for 5 communicating digital information between two components on a circuit board can suffice for this link. Methods of digitizing and communicating control signals originating from infrared transmitters are described in detail in Part II of this disclosure.

10 5) Example #1

Referring to Figs. 21a, 22, 24, 24a, 25a, 26a, and 27, the following is an example of the processing of non-telephone signals in transceiver/switch 400. Assume that line 402 is a fiber optic cable transmitting high frequency 15 optical impulses that represent frequency modulated encoding of a group of signals with a bandwidth of 5,000 Mhz. Among the individual signals expressed in the 5,000 Mhz band are 50 standard amplitude modulated NTSC signals confined within adjacent 6 Mhz channels. These are 20 expressed between the frequencies of 2000 Mhz and 2300 Mhz.

One of the functions of the communication system of this invention is to transmit any of the individual signals expressed between 2000-2500 Mhz on demand to video receivers 419 and transceiver 491c connected to local 25 networks 411a-411c. Furthermore, the system must allow the users to indicate their video selections by using infrared remote control transmitters 493a, 493b, and 493c shown in Fig. 21a.

Communication line 402 also accommodates 30 communication of signals in the opposite direction, away from transceiver/switch 400. A second task of the communication system is to allow video transmitters 417 and transceiver 491c to transmit signals onto line 402.

The light impulses from communication line 402 are 35 received by interface 409. That component responds to

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these impulses by producing a frequency demodulated electrical version of the 5000 Mhz signal encoded therein. Block converter 423 in interface 409a selects the frequencies between 2000 Mhz and 2500 Mhz, and converts 5 them to voltage variations between 100 Mhz and 600 Mhz.

The 500 Mhz wide, composite electrical signal provided by interface 409 is transmitted to splitter 426' in signal distribution subsystem 403a. Splitter 426' splits the input energy four ways, transmitting the signal 10 to demodulators 426 and also along path 420b to control signal processor 420.

Referring also to Fig. 28, demodulators 426 react in the following manner. In response to signals fed from master controller 415 over link 446a, demodulator 426a 15 selects and basebands the signal between 176 Mhz and 182 Mhz (video signal U). Similarly, demodulator 426b selects and basebands the 6 Mhz AM signal between 188-194 Mhz (video signal V), and demodulator 426c selects the signal between 200-212 Mhz, which is a digital signal conforming 20 to the "10BaseT Ethernet" standard (digital signal Y), and converts it to a demodulated signal at baseband. Thus, two ordinary NTSC video signals are selected from line 402, basebanded, and provided to switch 462a along two separate conductive paths. A third conductive path provides a 12 25 Mhz wide computer signal.

Switch 462a applies the output of demodulator 426a (video signal U) onto the path leading to modulator 410a, the output of demodulator 426b (video signal V) onto the paths leading to modulators 410b and 410d, and the output 30 of demodulator 426c (digital signal Y) onto the path leading to modulator 410c.

Modulators 410 modulate their input signals, converting them to frequency bands between 1 Mhz and 22 Mhz. These are the frequencies used to transmit signals 35 from transceiver/switch 400 to local networks 411.

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Specifically, modulators 410a and 410b amplitude modulate video signals U and V, respectively, to produce RF signals at 40dB mV between 1-6 Mhz in each case. (The frequency band between 1 and 6 Mhz can be used to provide a standard 5 6 Mhz NTSC channel if the part of the lower vestigial sideband between 0-1 Mhz is filtered out. This technique is described in Part II of this disclosure.) Modulator 410d, on the other hand, converts video signal V to an FM signal at 40dB mV between 7 and 22 Mhz, and modulator 410c 10 converts digital signal Y to a signal confined between 6 and 18 Mhz. Switch 401 receives the outputs of modulators 410a-410c and applies them to paths 478a-478c, respectively. Switch 401 also applies the output of modulator 410d to path 478a and couples the output of 15 modulator 410b onto path 478c. Thus, path 478a conducts both video signal U and video signal V (in different frequency bands), path 478b conducts video signal V, and path 478c conducts both video signal V and digital signal Y (in different frequency bands).

20 The signals applied to paths 478a-478c transmit to signal separators 413a-413c, respectively. Those components feed the signals onto extended pairs 405a-405c, respectively, using techniques described below.

The signals transmit across pairs 405a-405c to local 25 network interfaces 404a-404c, respectively, each of which converts the signals as necessary to enable them to be transmitted over respective local networks 411a-411c. Specifically, local network interface 404a converts video signal V to an AM signal in the frequency band between 30 24-30 Mhz and video signal U to an AM signal in the frequency band between 12-18 Mhz. Meanwhile, local network interface 404b converts video signal V to an AM signal in the frequency band between 54-60 Mhz (corresponding to VHF channel 2). Finally, local network interface 404c converts 35 video signal V to the AM signal between 12-18 Mhz, and

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expresses digital signal Y between the frequencies of 18-40 Mhz. Techniques to perform these conversions are described below.

After this conversion, local network interfaces 404 amplify the signals and retransmit them onto the respective local networks 411. Once applied to local networks 411, signals U, V, and Y are received by video receivers 419 and transceiver 491c. Video receivers 419 convert signals V and U to tunable frequencies before transmitting them to connected televisions 492, and transceiver 491c converts its signal to a form appropriate for computer 495c. Video receivers 419a and 419a', in particular, apply a single upshift of 186 Mhz to energy between the frequencies of 12 Mhz and 30 Mhz, converting signals U and V to video signals with picture carriers at 199.25 and 211.25 Mhz, (i.e. VHF channels 11 and 13), respectively. A design for a video receiver that performs such a block conversion is given in Part II of this disclosure, and a design for transceiver 491c is given in Part I of this disclosure. These conversions allow users at local networks 411a and 411b to watch video signal V, those at local network 411a can also watch video signal U, and computer 495c at local network 411c can receive digital signal Y, which is an "EtherNet" signal from communication line 402.

Meanwhile, RF transmitters 417 connected to local networks 411 apply signals to those networks that transmit in the opposite direction. These are received by interfaces 404, which in turn apply them to pairs 405. The signals then transmit to signal separators 413 in transceiver/switch 400. Those components direct the signals along paths 479 to amplifiers 408 in collection subsystem 407a of processor 418. All of these signals transmit across extended pairs 405 at frequencies between 24 and 100 Mhz, a band that does not overlap with the band in which signals transmit in the opposite direction (i.e.,

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1Mhz - 22Mhz).

(Techniques embodied in local networks interfaces 404 that receive signals from local networks 411, convert them, and transmit them across extended pairs 405 are 5 described below. The routing of these signals by signal separators 413 is also described below.)

An example of the signals transmitted by the RF transmitters 417 connected to local networks 411 and the conversions performed by local network interfaces 404 10 follows. Assume that video transmitter 417b inputs an NTSC video signal (video signal W) from camera 494b and feeds it onto local network 411b amplitude modulated between 6-12 Mhz. This signal is received by local network interface 404b, converted to an FM signal between 24-54 Mhz, 15 amplified, and applied to extended pair 405b. At transceiver/switch 400, video signal W transmits to signal separator 413b, which applies it to amplifier 408b. Meanwhile, video signal X is generated by camera 494c and transmits from video transmitter 417c to amplifier 408c in 20 an identical manner (via interface 404c, extended pair 405c, and signal separator 413c).

Transceiver 491c, meanwhile, receives a digital signal from computer 495c. That signal carries 1 Mbits/sec of information, (less than digital signal Y) and is called 25 digital signal Z. Transceiver 491c expresses this signal between 1-6 Mhz, and applies it to local network 411c where it is intercepted by local network interface 404c. Interface 404c encodes this signal using frequencies between 54-100 Mhz and transmits it onto extended pair 30 405c. The signal transmits across to transceiver/switch 400. Because it is expressed at relatively high frequencies, signal Z is received with a lower SNR, but its wider bandwidth allows reception with a low error rate. At transceiver/switch 400, digital signal Z transmits through 35 signal separator 413c to amplifier 408c.

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The signal reaching amplifier 408c covers the frequencies between 24 Mhz to 100 Mhz and includes both video signal X and digital signal Z from local network 411c. Under instructions from master controller 415, 5 switch 429 directs the output of amplifier 408c to both of demodulators 416b and 416c. Meanwhile, video signal W reaches amplifier 408b. Upon output from amplifier 408b, switch 429 directs that signal to demodulator 416a.

Under the control of controller 415, each 10 demodulator 416b, 416c processes only one of the two individual signals that constitute their inputs. Specifically, demodulator 416b demodulates video signal X, providing it at baseband frequencies to modulator 428b, while processor 416c demodulates digital signal Z, 15 providing it at baseband frequencies to modulator 428c. Processor 416a, meanwhile, demodulates video signal W, providing it at baseband frequencies to modulator 428a.

(These signals also transmit along paths 488. Because signal distribution subsystem 403a is not equipped 20 to input signals from these paths, however, signals transmitting along paths 488 are not received.)

Modulators 428 convert their inputs to RF frequencies. Specifically, modulator 428a converts video signal W to a modulated form between 400-406 Mhz. 25 Similarly, modulator 428b converts video signal X to a modulated form between the frequencies of 406-412 Mhz, and modulator 428c converts digital signal Z to a modulated form between the frequencies of 412-424 Mhz.

These three signals are fed to coupler 428'. That 30 component combines the three signals and transmits them to interface 409. Interface 409 then encodes the energy between 400-424 Mhz in this input signal into light impulses which it applies to communication line 402.

Control signals are also transmitted from local 35 networks 411 to transceiver/switch 400. At local networks

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411a, control signal A is introduced by IR remote control transmitter 493a in the form of light patterns. These are detected by video receiver 419a, converted to an electrical signal with a .5 Mhz bandwidth centered at 23 Mhz, and fed 5 onto local network 411a. Control signal A is then intercepted by local network interface 404a and fed onto extended pair 405a between the frequencies of 22.75-23.25 Mhz. It transmits to transceiver switch 400, passing through signal separator 413a to paths 479a and 477a. Path 10 479a leads to amplifier 408a. Although this path may connect to one of demodulators 416, control signal A will transmit no further because demodulators 416 do not demodulate signals in the band between 22.75-23.25 Mhz.

Control signal A transmits across path 477a through 15 filter 427a to demodulator 443a in control signal processor 420 (Fig. 27). That component basebands the signal, passing it to digitizer 436 which converts the signal to digital form. Finally, this digital representation of control signal A is transmitted to master controller 415. 20 Control signals B and C are created by IR remote control transmitters 493b and 493c and transmit to master controller 415 in a similar manner using the same frequencies.

Following is an example of a change in channel 25 selection. As explained above, video signal U is part of the 5000 Mhz signal transmitting on line 402. Specifically, assume that video signal U spans the frequencies between 2076 Mhz and 2082 Mhz, which are translated by interface 409 to the band between 176-182 30 Mhz. This band is selected when demodulator 426a converts it to the "intermediate" frequency. In response to a control signal from local network 411a, however, master controller 415 can instruct demodulator 426a to demodulate a different channel, such as the one between 182 Mhz and 35 188 Mhz, thereby "assigning" a new channel to video signal

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U:

Fig. 28 shows a table which summarizes the signals, transmission direction, and channels used for the communication described in this example.

5 G. Transmitting Signals from one Local Network to a Second Local Network (Figs. 21b, 25b)

Signal distribution subsystem 403b, an alternative embodiment of signal distribution subsystem 403, is shown in Fig. 25b. There are only two differences between this 10 embodiment and that of subsystem 403a. One is that switch 462b replaces switch 462a. The second difference is that signals from signal collection subsystem 407a (Fig. 26a) transmit at baseband along paths 488 to switch 462b, providing four extra inputs to that switch. Thus, switch 15 462b can (under the direction of master controller 415 via link 446b) provide signals recovered from local networks 411, in addition to signals provided from communication line 402, to modulators 410. This allows communication between the local networks 411.

20 Following is an example of communication conducted by a system that includes signal distribution subsystem 403b. Referring to Fig. 21b, a private telephone network connecting offices 512a-512e (collectively, offices 512) is established by PBX ("private branch exchange") 500 and 25 extended pairs 405a-405e that connect between each office and PBX 500. PBX 500, which is located in wiring closet 501, also connects to local exchange 475 (i.e. the public telephone network) through cable 475', which provides two lines of service. Such a configuration represents a typical 30 office telephone system.

Transceiver/switch 400 (Fig. 22) is also located inside wiring closet 501, interposing along the portions of extended pairs 405 that is within a few (e.g., 20) feet of PBX 500. The relatively short portions of extended pairs 35 405 connecting between transceiver/switch 400 and PBX 500 are called twisted pairs 476a-476c (collectively, 476).

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High capacity communication line 402 also connects to transceiver/switch 400.

Internal to each of offices 512 are several types of communication devices. (The communication devices 5 connected to offices 512d and 512e are not shown because the system shown in Fig. 21b provides only telephone communication with those offices.) Two of these, telephone devices 514a-514c (collectively, telephone devices 514) and video transceivers 509a-509c (collectively, video 10 transceivers 509), connect directly to the corresponding one of extended pairs 405. The wiring that connects these devices to the extended pairs 405a-405c is shown as local networks 511a-511c, respectively. Thus, in Fig. 21b, the telephone wiring that comprises each local network 511 is 15 simply two short telephone cables connecting to the associated extended pair. Each telephone device 514 connects to the associated local network 511 via a low-pass filter (LPF). As described in Part I of this disclosure, these filters prevent telephone devices 514 from affecting 20 RF energy on the local networks 511. (These filters may be provided as part of splitter 161, which is described in Part I of this disclosure.)

Each video transceiver 509 connects to the corresponding one of extended pairs 405 to transmit and 25 receive video signals. Video transceivers 509 also detect infrared signals, convert them to electrical signals, and feed them onto the extended pairs 405. Individually, each of these processes is described in U.S. Patent No. 5,010,399 and Part I of this disclosure. Part I of this 30 disclosure also describes how to combine RF transmitters and receivers into a single device that communicates through a single connection to active telephone wiring.

Video signals received by transceivers 509 are passed to video displays 508a-508c (collectively, video 35 displays 508). Video sources 507a-507c (collectively,

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video sources 507) also connect to video transceivers 509. video sources 507 are devices such as video cameras, VCRs, or digital devices, that create electronic signals containing the information necessary to display the type of 5 video pictures addressed in this disclosure. These signals are passed to the connected one of video transceivers 509. The components in offices 512d and 512e are not shown.

Video sources 507a, 507b, and 507c each create a single video signal, called video signals Va, Vb, and Vc, 10 respectively. These signals are fed to video transceivers 509a, 509b, and 509c. Using amplitude modulation, video transceivers 509 convert their input signals, expressing them between the frequencies of 1 Mhz and 6 Mhz, according to the spectral distribution shown in Fig. 23a. (As noted 15 earlier, AM video signals may suffer from crosstalk interference, even at very low frequencies. Thus, the use of AM in this example is arbitrary, and the use of FM may be indicated if the crosstalk loss is small.) These signals are then transmitted onto the network 511 of 20 twisted pair wiring internal to offices 512a, 512b, 512c, respectively.

Because local network interfaces 404 are not provided, the signals applied by video transceivers 509 to local networks 511 transmit directly onto extended pairs 25 405a-405c. If the wiring internal to the office is a single wire, this wiring can be simply be considered an extension of extended pairs 405a-405c.

The signals applied to extended pairs 405 transmit to signal separators 413 in transceiver/switch 400 (Fig. 30 22). Signal Va is routed by signal separator 413a to both filter 427a in control signal processor 420 (Fig. 27), and amplifier 408a in subsystem 407a of processor 418 (Fig. 26a). Signal Va is blocked by filter 427a, but is transmitted by amplifier 408a through switch 429 to 35 demodulator 416a. That component demodulates signal Va,

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passing it along path 488a to signal distribution subsystem 403b. In a similar manner, signals Vb and Vc are applied at baseband to paths 488b and 488c.

Control signals are also transmitted from offices 5 512. These control signals are infrared (IR) signals issued by infrared transmitters not shown in the figures. Using techniques described in U.S. Patent No. 5,010,399 and Part I of this disclosure, the IR signals are detected by video transceivers 509, converted to electrical signals, and 10 transmitted onto local networks 511. These signals are applied to extended pairs 405 and transmit to signal separators 413 following the same routes, described above, followed by the video signals. Control signals from video transceiver 509c, for example, are routed by signal 15 separator 413c to both filter 427c in control signal processor 420, and amplifier 408c in subsystem 403b. These signals are demodulated by demodulator 443c, digitized by digitizer 436, and transmitted to master controller 415.

As described above, video signals Va, Vb, and Vc, 20 transmit along paths 488 to switch 462b in subsystem 403b. That component switches these signals, connecting Va to modulator 410a, Vb to modulator 410b, and Vc to modulator 410c. Using frequency modulation, modulators 410a-410c express their inputs signals between the frequencies of 25 7-22 Mhz. These signals are all applied to switch 401.

Switch 401 switches signal Vb (output by modulator 410b) onto paths 478a and 478c, and signal Vc onto path 478b. Thus, these signals transmit through signal separators 413 and across extended pairs 405 arriving at 30 offices 512. Because of the connections made by switch 401, signal Vb (originating in office 511b) transmits to offices 512a and 512c, and signal Vc (which was sent from office 511c) transmits to office 512b. Internal to offices 512, video transceivers 509 receive these signals and 35 provide them to video displays 508.

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It is thus apparent that the system just described allows workers in offices 512a and 512c to hold a video conference with a worker in office 512b. Initially, the workers in office 512a and 512c watch the worker in 512b, 5 while the worker in office 512b watches the worker in office 512c. By sending a control signal to master controller 415, as described above, the worker in office 512b can switch to display the signal from office 512a. This is done as follows. In response to a signal from 10 office 512b, master controller 415 sends a signal to switch 401, instructing it to connect the output of modulator 410a to path 478b instead of connecting the output of modulator 410c to path 478b. Because modulator 410a provides signal Va on output, this effects the desired switching.

15 Now assume communication line 402 is a coaxial cable that carries three 6 Mhz video signals between the frequencies of 200-218 Mhz. A worker in office 512b can also select a video signal from communication line 402 from transmission to his or her office. This is done in the 20 following manner.

Signals between 200-218 Mhz on communication line 402 transmit to interface 409a where they pass through circulator 421 to block converter 423. That component downshifts these signals to the frequencies between 54 and 25 72 Mhz, and passes them through splitter 426' in subsystem 403b to demodulators 426. Next, a control signal is sent from video transceiver 509b to master controller 415, as described above. In response to this signal, master controller 415 directs demodulator 426a to demodulate the 30 signal between 60 Mhz and 66 Mhz, providing it at baseband to switch 462b. In response to another signal from master controller 415, switch 462b connects this signal to modulator 410d. Finally, master controller 415 commands switch 401 to connect the output of modulator 410d (rather 35 than the output of modulator 410a) to path 478b. Because

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signals passed to path 478b transmit, as described above, to office 512b, the desired signal switching is achieved.

H. A Third Embodiment of Signal Distribution Subsystem 403 (Fig. 25c)

5 Signal distribution subsystem 403c, which represents a third embodiment of signal distribution subsystem 403, is shown in Fig. 25c. In this embodiment, the demodulation and modulation processes are combined, and only one switch is provided. This has several advantages, which are described
10 below.

Signals transmitted from interface 409 are divided by splitter 426' along five paths. Four paths lead respectively to RF processors 485a-485d (collectively, RF processors 485). The fifth path, labelled path 420b, leads
15 to signal processor 420. The processing of these signals by RF processors 485 is described in the following paragraphs. The processing by control signal processor 420 is described in an earlier section of this disclosure.

Each RF processor 485 selects a channel from among
20 the multiple channels that comprise its input signal and converts the selected channel to the waveform, frequency, and amplitude at which it will transmit through a signal separator 413 and across an extended pair 405. As shown in Fig. 25c, in the first part of this process a selected
25 frequency band is shifted to an intermediate band (using a frequency shifter and local oscillator) and the result is filtered and then demodulated. This creates a basebanded version of the selected signal. (Demodulation of an AM signal involved a process called "detection," while
30 demodulation of an FM signal requires a process called "decoding.")

Selection of channels in RF processors 485 is achieved by tuning the frequency of the local oscillator (l.o.) This is done in response to signals from master
35 controller 415, which are sent over link 446a.

After demodulation, a pre-emphasis process is

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optionally performed on the basebanded signal to compensate for spectral tilt. As described above and in Part I of this disclosure, this process amplifies the higher frequencies to compensate for the greater attenuation of 5 those frequencies during transmission. After pre-emphasis, the signal is modulated to its final waveform and frequency. (If AM waveforms are used, the modulation process involves mixing the signal with the frequency of a local oscillator. If FM waveforms are used, the modulation 10 process involves "encoding" voltage variations of the signal as frequency deviations of a carrier provided by the local oscillator.) After modulation, the signal is amplified and applied to switch 487.

As described above, each RF processor 485 selects 15 one signal from its input channels and provides that signal at an RF channel. Thus, RF processors 485 are similar to ordinary "cable converters" that receive a band of multiple video signals, select one channel, and output the signal within an different RF channel.

20 The signals exiting RF processors 485 are labelled "selected signals" in Fig. 25c. Each one will be transmitted to a single signal separator 413, and thus will be transmitted over exactly one extended pair 405. The assignment of the outputs of RF processors 485 to signal 25 separators 413 is accomplished by switch 487 under the control (via link 446c) of master controller 415.

Switch 487 receives the selected signals from RF processors 485, and switches them over paths 478a-478c to signal separators 413a-413c. The design and operation of 30 switch 487 is similar to that of switch 462a. As such, switch 487 responds to control signals sent from master controller 415. These signals are transmitted over link 446c. Master controller 415 may connect the output of several of RF processors 485 to the same one of paths 478. 35 Master controller 415 must ensure, in that case, that these

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outputs do not overlap in frequency.

Subsystem 403c is efficient for systems in which it is unusual to have duplication within the group of signals selected to be sent to local networks 411. Provision of 5 cable TV signals to a small apartment unit is a good example of such a situation. Assume, for example, that communication line 402 carries 60 cable TV signals to a 20 unit apartment house, and that an embodiment of the communication system disclosed herein was installed to 10 provide a single signal to each of those units. This requirement could be satisfied if the embodiment included subsystem 403c and 20 RF processors 485. It should be clear, furthermore, that any embodiment with fewer than 20 demodulators (which are used for channel selection) and 20 15 modulators would not suffice. (Specifically, they would fail whenever the 20 units each requested a different one of the 60 signals.)

If one unit required provision of more than one signal at a time, the requirement could be satisfied by 20 adding an extra RF processor 485. For example, assume that 20 RF processors 485 are provided, and their outputs are switched so that they transmit to different ones of the 20 units. Assume further that they each produce a single video signal between the frequencies of 1-6 Mhz. If one 25 apartment unit required transmission of an additional signal, this could be satisfied by providing an extra one of RF processors 485, whose output was confined between the frequencies of 6-12 Mhz, and that this output would be combined with the other signal transmitting to the unit in 30 question.

I. Alternative Signal Collection Subsystem 407b (Fig. 26b)

Signal collection subsystem 407b, which represents an alternative embodiment of signal distribution subsystem 407, is shown in Fig. 26b. This embodiment is simpler and 35 less expensive than subsystem 407a, yet it allows each

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local network 411 to transmit a single signal over extended pairs 405 and to have that signal received by transceiver/switch 400 and applied to communication line 402.

5 Referring to Fig. 26b, signals from signal separators 413 transmit over paths 479 to RF converters 486a-486c (collectively, RF converters 486) within subsystem 407b. Because they prepare the individual signals collected from extended pairs 405 to be combined
10 onto a single conductive path, RF converters 486 are very similar in function to modulators 428 of subsystem 407a. Each RF converter 486 is fixed to shift the energy of its input signal within a particular frequency band to a different band. As shown in Fig. 26b, this process
15 includes mixing the input signal with a local oscillator, and filtering of the resulting output (e.g., to remove all but one sideband). This process creates a new signal, with identical information content, within the new frequency band.

20 The local oscillators used by each of RF converters 486 are such that the resulting output frequency bands of the three converters 486a-486c do not overlap. This allows the outputs to be combined onto a single conductive path. In a preferred embodiment, the frequency bands confining
25 the outputs of RF converters 486 are adjacent in addition to non-overlapping. This minimizes the width of the band occupied by the combined signals.

The signals produced by RF converters 486 are all transmitted to coupler 428'. That component combines the
30 individual signals onto a single conductive path, and passes it to interface 409, which applies the combined signal onto communication line 402, as described above.

1) Example # 2

Following is an example of communication between
35 transceiver/switch 400 and local networks 411 using an

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embodiment of the communication system that includes signal distribution subsystem 403c, signal collection subsystem 407b, and interface 409a.

Communication line 402 provides NTSC cable signals 5 at frequencies between 54 Mhz and 850 Mhz. One of the tasks of the communication system in this example is to make the signals between the frequencies of 300 Mhz and 480 Mhz available to local networks 411. Another task is to receive signals from local networks 411 and to add them to 10 this cable between the frequencies of 850 Mhz and 900 Mhz.

The signal from communication line 402 transmits to circulator 421 (Fig. 24a) which feeds it to block converter 423 in interface 409. That device downshifts the band between 300 to 480 Mhz to the band between 54 to 234 Mhz 15 (using an L.O. frequency of 246 Mhz). The result is fed to splitter 426' in subsystem 403c (Fig. 25c). That component splits the energy of the signal five ways, transmitting the signal to RF processors 485 and also along path 420b to control signal processor 420.

Using the system, described above, for communication with master control 415, users at local network 411a select 20 a first channel between 60 and 66 Mhz, and a second channel between 176 and 182 Mhz. In response, master controller 415 instructs converter 485a, via link 446a, to convert the first channel to an AM signal confined between 1-6 Mhz, and it also instructs converter 485b to convert the second channel to an AM signal between 6-12 Mhz. These signals are 25 passed to switch 487. Similarly, users at local network 411b select a third channel between 66 Mhz and 72 Mhz (VHF channel 3) which is converted by RF processor 485c and is provided as an AM signal between the frequencies of 1-6 Mhz. Finally, users at local network 411c select a fourth channel between 182-188 Mhz which is converted by RF processor 485d to the frequencies between 1-6 Mhz. (A 30 standard 6 Mhz NTSC channel can fit between the frequencies 35

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1-6 Mhz by filtering out the part of the vestigial sideband between 0-1 Mhz. This is described more fully in Part II of this disclosure.) Each of the signals output by RF processors 485 transmits to switch 487. In response to 5 signals sent by master controller 415 on link 446c, switch 487 combines the outputs of RF processors 485a and 485b and connects them to path 478a, thus transmitting these outputs to signal separator 413a. Similarly, the output of RF processor 485c is transmitted over path 478b to signal 10 separator 413b, and the output of RF processor 485d is transmitted over path 478c to signal separator 413c. Using techniques described below, signal separators 413 route these signals to the corresponding ones of extended pairs 405. The four video signals thus transmit local networks 15 411.

Because the highest frequency transmitted from transceiver/switch 400 to local networks 411 is 12 Mhz, in this case, the signals will suffer a relatively small amount of attenuation as they transmit across extended 20 pairs 405. Thus, there is a relatively high probability that these signals will arrive at local networks 411 with energy levels sufficient to be efficiently and clearly transmitted to video receivers 419. It is assumed that such is the case in this example. Thus, video receiver 25 419a receives one video signal amplitude modulated between 1-6 Mhz, and another amplitude modulated between 6-12 Mhz. It imparts an upwards frequency shift of 60 Mhz to these signals, converting them to the frequencies between 60-72 Mhz, i.e., VHF channels 3 and 4. This signal is provided to 30 TV 492a. Similarly, video receivers 419b and 419c shift their inputs so that each provides a single signal at VHF channel 3 to both TV 492b and TV 492c, respectively.

Meanwhile, transmission of signals from local networks 411 to transceiver/switch 400 is also provided. 35 Specifically, video transmitter 417b receives a signal from

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video camera 494b, converts it to a single 30 Mhz FM video signal between the frequencies of 12-42 Mhz, and transmits it onto local network 411b and across extended pair 405b to transceiver/switch 400. Although it suffers significantly 5 greater attenuation than the lower frequency video signals transmitting in the opposite direction, its wide bandwidth compensates by allowing the receiver to tolerate a lower SNR. This signal transmits to signal separator 413b. That component directs the signal to RF converter 486b (Fig. 10 26b). Video transmitter 417c feeds a second video signal across extended pair 405c to converter 486c using a similar process.

Within subsystem 407b, RF converter 486b converts its input signal to a 6 Mhz AM signal between 24-30 Mhz, 15 and converter 486c converts its input to a 6 Mhz AM signal between 30-36 Mhz. These signals are passed to coupler 428' which combines them onto one conductive path and transmits them to block converter 447 in interface 409 (Fig. 24a). Block converter 447 then shifts these signals 20 upwards to the frequency band spanning 850-862 Mhz. Block converter 447 then amplifies the shifted signal, and passes it through circulator 421b and onto communication line 402. Once on that medium, these two signals transmit in the opposite direction of the 30 NTSC signals that transmit 25 between 300-480 Mhz.

J. Transmission and Recovery of Signals from a Single Twisted Pair in a Bundle (Figs. 29a-29b)

A primary purpose of signal separators 413 is to receive signals from processor 418 and apply them to 30 extended pairs 405 while simultaneously receiving signals from extended pairs 405 and transmitting them to processor 418 and to control signal processor 420. To perform this function, each signal separator 413 is connected between an extended pair 405 and the corresponding one of twisted 35 pairs 476.

The remaining part of the description of signal

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separators 413 will be cast in terms of signal separator 413b and local network 411b. Two embodiments of signal separators 413 will be described. One embodiment, shown in Fig. 29a and described first, is appropriate when telephone signals transmit over extended pairs 405 in the ordinary manner, i.e., at voiceband frequencies. The other embodiment is appropriate when telephone signals transmit over extended pairs 405 at frequencies above voiceband, as depicted in Fig. 23b. This embodiment is shown in Fig. 10 29b.

Referring to Fig. 29a, signals that are applied to signal separator 413b are converted and routed in the following manner:

- 1) Telephone signals from local exchange 475
15 transmit across extended pair 476b and through filter 474b, entering the "exchange" port of separator 413b. These signals are applied directly to the "local" port and exit the "local" port unchanged.
- 2) Telephone signals from local network 411b
20 transmit across extended pair 405b, presenting at the "local" port. These signals exit the "network" port, also unchanged.
- 3) Signals recovered from communication line 402
25 that are processed by processor 418 and output by switch 401 (Fig. 25a) transmit across path 478b to the "distribution" port of signal separator 413b. These signals exit the "local" port.
- 4) Infrared control signals detected by video receiver 419b and fed onto local network 411b and
30 transmitted (after reception, processing and retransmission by local network interface 404b, if 404b is provided) across extended pair 405b are applied to the "local" port. These signals are targeted for master controller 415, and are routed through the "control" port and along path 477b
35 to filter 427b in control signal processor 420 (Fig. 27).

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These signals also transmit through the "collection" port and along path 479b, but are ignored by signal selection subsystem 403.

5) Video signals fed by video transmitter 417b onto local network 411b transmit (after reception, processing and retransmission by local network interface 404b, if 404b is provided) across extended pair 405b to the "local" port. These signals are routed through the "collection" port and transmit across path 479b to amplifier 408b. (Similarly, 10 digital signals fed by transceiver 491c onto local network 411c transmit across extended pair 405c and are routed to amplifier 408c.) These signals also transmit through the "control" port and along path 477b to filter 427b in control signal processor 420. Those signals are blocked 15 from further transmission, however, by filter 427b.

In the embodiment shown in Fig. 29a, signals transmitting through separator 413b are not processed, i.e. they are not amplified, or converted in frequency or waveform.

20 The major components of signal separator 413b are high pass filter 451, coupling network 459, splitter 458, and invertor 496. These components provide the signal routing and processing described above. It will be appreciated that other embodiments of signal separator 413b 25 that achieve the signal routing and signal conversion described above are also possible.

Transmission of telephone signals through signal separator 413b is straightforward. A simple conductive path connects between the "local" port and the "exchange" 30 port, thereby connecting low pass filter 474b on twisted pair 476b with extended pair 405b. Because low pass filter 474b passes all voiceband energy, this connection completes an simple unbroken conductive path between local exchange 475 and local network interface 404b. High pass filter 451 35 prevents any telephone signals from diverting towards

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coupling network 459.

Low pass filters 474 block transmission of the high frequency signals transmitting through signal separators 413 between processor 418 and local network interfaces 411.

- 5 In addition to preventing the "splitting loss" of these high frequency signals, filters 474 prevent them from creating violations of governmental regulations by conducting onto the public telephone network. Part 68 of the FCC regulations in the U.S., for example, severely
10 limits the energy that can be conducted onto the public network by signals above voiceband and below 6 Mhz.

Video and other non-telephone signals transmitting over extended pair 405b from local network 411b transmit through the "local" port. These signals pass through high
15 pass filter 451 to coupling network 459. They are blocked from transmitting towards local exchange 475 by low pass filter 474b (Fig. 22).

At coupling network 459, directional coupling directs signals received from extended pair 405b to
20 splitter 458, isolating these signals from transmitting through invertor 496 (which is described below) to path 478b leading to subsystem 403. Reverse isolation in invertor 496 can also block these signals from path 478b. If this isolation is not provided, these signals may
25 transmit through switch 401 to the output of modulators 410, where they will be blocked by the reverse isolation of those components. (If subsystem 403 follows the embodiment shown in Fig. 25c, reverse isolation will be provided by RF processors 485.)

30 The energy of the non-telephone signals is divided by splitter 458, so the signals transmit across path 477b to control signal processor 420 and across path 479b to signal collection subsystem 407. An amplifier, (not shown) can be provided internal to splitter 458 to compensate for
35 the 3dB of energy lost during splitting.

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Control signals targeted for master controller 415 that transmit across path 477b continue through filter 427b (Fig. 27) in control signal processor 420 to demodulator 443b. (All signals at the frequencies covered by the 5 passband of filter 427b are considered to be intended for communication with master controller 415.) Processing of these signals internal to processor 420 is described below. Other signals, such as video signals, transmitting along path 477b will be blocked by filter 427b.

10 Signals transmitting across paths 479b to subsystem 407a (Fig. 26a) transmit to amplifier 408b. These signals are amplified and transmitted through switch 429 to one or more demodulators 416. Video signals and signals other than the control signals intended for communication with 15 master controller 415 are then subject to selection by demodulators 416, as described above. Signals not selected terminate at that point. If subsystem 407b is provided in place of subsystem 407a, the same type of signal selection takes place at RF converter 486b.

20 Signals received by processor 418 from communication line 402 that are processed by processor 418 and output by switch 401 (Fig. 25a) transmit across path 478b to the "distribution" port of signal separator 413b. These signals transmit through invertor 496 to coupling network 25 459. Directional coupling internal to coupling network 459 directs these signals to high pass filter 451, while isolating them from transmitting to splitter 458. The signals from processor 418 emerge from filter 451 and transmit onto extended pair 405b.

30 Invertor 496 is supplied to reduce the possibility, described above, of increased crosstalk interference when the same video signal transmits within the same frequency band to multiple local networks 411. This possibility is reduced as follows. Invertor 496, which is an ordinary and 35 inexpensive electronic component, implements a 180 degree

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phase shift across all frequencies. This phase shift is accomplished by simply converting negative voltages to positive, and vice versa. Thus, the polarity of the output of invertor 496 is the opposite of that of its input, and 5 by placing an invertor 496 as shown in Fig. 29a in approximately half of signal separators 413, the likelihood that the electric fields created by each of the pairs in the group of extended pairs 405 will cancel each other is increased. A component that implements a slight delay in 10 transmission can produce a similar affect if the delay times are slightly different for each of signal separators 413. Both methods tend to prevent the interference from adding coherently.

In addition to providing directional multiplexing, 15 coupling network 459 also balances the signals transmitting towards filter 451, and matches the impedance of the conductive path internal to signal separator 413 with the impedance of extended pair 405b. This tends to reduce the radiation of these signals and improve the efficiency of 20 the transfer of energy between pairs 405 and signal separators 413.

Balancing and impedance matching circuitry are shown in Figs. 6 and 7 of U.S. Patent No. 5,010,399, for a coupling network that served as a junction of three paths. 25 Those skilled in the art can convert the wound-torroid described therein to achieve the balancing and impedance matching results for this case.

If directional multiplexing in coupling network 459 is not sufficient to prevent transmission of signals from 30 subsystem 403 from transmitting to splitter 458, filtering internal to splitter 458 can prevent these signals from exiting the splitter onto paths 477b or 479b. This type of filtering is possible because, as described above, the frequencies used by signals transmitting towards local 35 networks 411 are different from the frequencies used by

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signals transmitting towards transceiver/switch 400.

1) Example #3

Referring also to Fig. 28, the routing of each of the signals used in the previous example is now described.

5 Signals communicating with local network 411a are routed by signal separator 413a, those communicating with local network 411b are routed by signal separator 413b, and those communicating with local network 411c are routed by signal separator 413c.

10 Video signal U and video signal V exit switch 401 on conductive path 478a. Video signal U is confined within the 1-6 Mhz band, as shown in Fig. 23a, and video signal V is confined between 7-22 Mhz. These signals transmit along path 478a to signal separator 413a, transmitting through 15 invertor 496 to coupling network 459. They continue on through high pass filter 451 and onto extended pair 405a.

Simultaneously, video signal V exits switch 401 along path 478b at frequencies between 1-6 Mhz. Signal V transmits to signal separator 413b, transmitting through 20 invertor 496 to coupling network 459. It continues on through high pass filter 451 and onto extended pair 405b. Video signal V follows a similar path at similar frequencies, exiting switch 401 along path 478c to signal separator 413c, and transmitting onto extended pair 405c.

25 Meanwhile, digital signal Y exits switch 401 confined between the frequencies of 6-18 Mhz. It follows a path to extended pair 405c using the same route as video signal V.

Video signals W and X, digital signal Z, and control 30 signals A, B, and C all transmit in the reverse direction. Video signal W and control signal B are both transmitted onto local network 411b. These signals are intercepted by local interface processor 404b and retransmitted across extended pair 405b to signal separator 413b. Inside that

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signal separator 413b, video signal W and control signal B pass through high pass filter 451 to coupling network 459. These signals are directed by that network towards splitter 458. That component splits the signal energy, transmitting 5 half along path 477b to filter 427b in processor 420 and half along 479b to splitter 408b in processor 418. Filter 427b allows only control signal B to pass through to be processed by control signal processor 420. (Ultimately, control signal B will communicate with master controller 10 415.) Video signal W and control signal B both pass along path 479b to amplifier 408b in collection subsystem 407a, and exit to switch 429. Only video signal W, however, is transmitted by switch 429 to demodulators 416.

Video signal X, control signal C, and digital signal 15 Z, meanwhile, are applied to local network 411c and transmit across extended pair 405c to signal separator 413c. The filtering and directional multiplexing internal to that component directs them through splitter 458 and across path 479c to amplifier 408c. The signals input to 20 splitter 408c also transmit across path 477c to filter 427c in signal processor 420.

Finally, control signal A transmits across extended pair 405a to signal separator 413a which directs it to filter 427a in control processor 420 and to amplifier 408a 25 in subsystem 407a.

2) Transmitting Telephone Signals Above Voiceband
(Fig. 29b)

The embodiment of signal separator 413b shown in Fig. 29b is now described. This embodiment is used when 30 signals received from communication line 402 are transmitted by transceiver/switch 400 across extended pair 405b using, in addition to higher frequencies, frequencies at voiceband. (The spectral distribution of these signals is shown in Fig. 23b.) As described above, signal 35 separator 413b and local network interface 404b cooperate, in this embodiment, to transmit telephone signals at

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frequencies above voiceband.

Referring to Fig. 29b, the major components of signal separator 413b are coupling network 422, telephone signal processor 424, and impedance matcher 480. Processor 5 424 works in conjunction with local interface 404b to communicate telephone signals across extended pair 405b at RF frequencies.

Telephone signals from local exchange 475 transmit at voiceband through low pass filter 474b (Fig. 22) and 10 through the "exchange" port of separator 413b to conversion circuitry 464, which is part of processor 424. Circuitry 464 converts all of these signals to RF frequencies. The converted signals include voice, ringing, and hookswitch signals. The converted telephone signals are transmitted 15 through bandpass filter 425 to coupling network 422.

Filter 425 passes energy within the bands occupied by the telephone signals in their RF form, but blocks all other signals, including voiceband signals. This prevents conversion circuitry 464 from loading down non-telephone 20 signals that transmit to processor 424.

The telephone signals transmitted from local exchange 475 always exit the "local" port of signal separator 413b because filters located on the paths exiting network 422 block these signals from exiting through the 25 "collection," "distribution," and "control" ports. (This filtering is described below.) These signals transmit onto extended pair 405b. They are received and converted back to their original form by local network interface 404b as will be described below. The reconverted signals are then 30 transmitted onto local network 411b as normal voiceband signals.

Telephone signals transmitting in the reverse direction, from telephone device 414b to local exchange 475, are converted in the following manner. Local network 35 interface 404b intercepts the signals from telephone device

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414b, which are at voiceband, converts them to RF signals, and transmits them across extended pair 405b. Processing of telephone signals by local network interfaces 404 is described in greater detail below.

5 Telephone signals in the RF band from extended pair 405b transmit through the "local" port of signal separator 413b to coupling network 422. These signals then transmit to telephone signal processor 424 but are blocked from exiting network 422 towards the "collection,"
10 "distribution," and "control" ports by filters connected to the paths leading to those ports. (Coupling network 422 is described in greater detail below.) These telephone signals pass through filter 425 to conversion circuitry 464 which converts them back to voiceband, and transmits them to
15 filter 474b and across twisted pair 476b to local exchange 475.

Means to convert telephone signals from voiceband to RF signals and back to voiceband are well known and can be used to implement the functions of conversion circuitry 464
20 and the companion conversion component in local network interfaces 404. Indeed, common cellular or cordless telephones convert voiceband, switchhook, and ringing signals to RF frequencies to transmit the signals over a wireless link to a telephonic communication line.

25 Routing of non-telephone signals through signal separator 413b (as shown in Fig. 29b) is now described. Coupling network 422 includes directional couplers 466 and 467 and splitter 468. Couplers 467 and 466 each have a joined port and left and right isolated ports. Signals
30 presenting at a joined port pass to through to each of the isolated ports. (The signal energy is evenly split.) Signals presenting at an isolated port exit through the joined port, but are blocked, (e.g. have a 30dB loss) from exiting the other isolated port.

35 Signals from extended pair 405b pass through the

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"local" port and present at impedance matcher 480. These signals include both telephone signals, control signals, and signals destined for transmission to communication line 402. Impedance matcher 480 matches the impedance of the 5 telephone line to the circuitry internal to transceiver/switch 400.

After passing through impedance matcher 480 these signals transmit to directional coupler 467, exiting through both of the isolated ports and transmitting to the 10 joined port of coupler 466 and splitter 468. Signals presenting at the joined port of coupler 466 exit both of the isolated ports. As can be seen by tracing the paths, signals exiting the isolated port leading towards switch 401 in subsystem 403 (i.e., the right isolated port of 15 coupler 466) pass through to modulator 410b where they are blocked (i.e. meet a high impedance) by the reverse isolation at the output of that device. A filter can be provided at the output of modulator 410b to prevent loading down of these signals.

20 From among the signals that pass out the left isolated port of coupler 466 leading towards processor 424, only telephone signals are received by processor 424. These are processed as described above. Non-telephone signals are blocked by filter 425 in that processor.

25 Signals from extended pair 405b that present at the joined port of coupler 467 and exit the left isolated port towards splitter 468 are split and routed to filter 427b in control signal processor 420 and amplifier 408b in subsystem 407 of processor 418. As will be described later 30 on, filter 427b blocks signals other than those at frequencies used by the control signals that communicate with master controller 415. Thus, processor 420 separates the special control signals from the group of "collected" signals.

35 As described above, signals presenting at amplifier

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408b are amplified and transmitted through switch 429 to demodulators 416. Video signals and signals other than telephone signals and control signals intended for communication with master controller 415 are then subject
5 to selection by demodulators 416, as described above. Signals not selected terminate at that point. (Thus, control signals and telephone signals will terminate.) If subsystem 407b is provided in place of subsystem 407a, the same type of signal selection takes place at RF converters
10 486.

As described above, the signals received by processor 418 from communication line 402 that are intended for transmission to local network 411b are output from switch 401 (in subsystem 403a, Fig. 25a). These signals
15 exit along path 478b, pass through the distribution port of signal separator 413b and through invertor 496 to the right isolated port on directional coupler 466 in coupling network 422. (This path can be traced in Figs. 22 and 29b.)

20 Signals passing through the right isolated port of directional coupler 466 exit through the joined port of coupler 466. (They are substantially blocked from exiting the left isolated port by the directional multiplexing of coupler 466; filter 425 blocks the portion of the energy
25 that exits from the left isolated port.) They then pass through the left isolated port of coupler 467, to the joined port of coupler 467. (They are blocked from exiting the other isolated port of coupler 467 by the directional multiplexing and, ultimately, by the reverse isolation of
30 modulators 410.) Finally, they pass though the joined port of coupler 467, through impedance matcher 480b onto extended pair 405b. The impedance matching enables these signals to feed onto extended pair 405b, which has a different impedance, without substantial signal refections.

35 K. Signal Processing at the Local Network Interface (Figs. 30-33)

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The signals fed to one of extended pairs 405 by transceiver/switch 400 are received at the opposite end by the corresponding one of local network interfaces 404 which processes these signals and retransmits them onto the 5 corresponding one of local networks 411. If two-way communication between transceiver/switch 400 and local networks 411 is performed, each local network interface 404 also receives signals transmitted onto local networks 411 and transmits them onto the corresponding one of extended 10 pairs 405.

The primary function of local network interfaces 404 is to process the signals intercepted from extended pairs 405 so that when they are retransmitted their ability to communicate to the RF receivers connected to local networks 15 411 will be enhanced. Processing of signals transmitting towards transceiver/switch 400 provides similar benefits.

A particularly important process performed by local network interfaces 404 is amplification. This allows signals transmitting along the transmission path between 20 transceiver/switch 400 and the RF receivers on local networks 411 to be amplified at an intermediate point, boosting their energy levels up to the maximum limit (i.e., the limit at which they radiate RF energy just below governmental limits.) This re-amplification will improve 25 the SNR at the receive end, increasing the attenuation that the signal can encounter along the transmission path while still being successfully received. Processing that converts signal waveform and frequency can also be useful, as described below.

30 In some embodiments, particularly those where a video signal is transmitted over one of extended pairs 405 at baseband frequencies (Fig. 23B), telephone signals transmit from transceiver/switch 400 to local network interfaces 404 at RF frequencies, having been converted 35 from voiceband by a telephone signal processor 424 in one

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of signal separators 413. When telephone signals transmit at RF frequencies, local network interfaces 404 convert the signals received from extended pairs 405 to ordinary voiceband telephone signals, and feed them onto the corresponding local networks 411 for reception by telephone devices 414 in the ordinary manner. Conversion also takes place in the opposite direction. I.e., voiceband telephone signals from devices 414 that transmit across local networks 411 are received by the corresponding local network interfaces 404, frequency converted, and applied to the corresponding one of extended pairs 405 at RF frequencies.

A general embodiment of a local network interface 404 is shown in Fig. 30. The description that follows will be cast in terms of local network interface 404b, but applies, of course, to any one of local network interfaces 404 shown in Fig. 21a.

Referring to Fig. 30, the principle components of local network interface 404b are the telephone signal processing section 470, general signal processing section 471, coupling networks 437 and 449, and high pass filter 463. All signals from extended pair 405b transmit to coupling network 437, and high-frequency (i.e., non-voiceband) signals from local network 411b transmit through high pass filter 463 to coupling network 449. Directional multiplexing and filtering in coupling networks 437 and 449, and filtering on paths connected to these coupling networks, cause the converging signals to be routed as follows. Telephone signals from extended pair 405b are blocked by filters 438, 445 in general signal processing section 471 and thus are routed through telephone signal processing section 470 and onto local network 411b (and are blocked from coupling network 449 by high pass filter 463). Telephone signals also transmit across the same path in the opposite direction. Non-telephone signals from extended

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pair 405b are routed to general processing section 471, and non-telephone signals from section 471 pass through coupling network 437 to extended pair 405b. Also, non-telephone signals from local network 411b transmit to 5 general processing section 471, and non-telephone signals from general processing section 471 transmit onto network 411b.

The transmission of telephone signals through local interface 404b and the details of telephone signal 10 processing section 470 are described first. That description also includes a description of two particular embodiments of coupling network 437. Several embodiments of general processing section 471 and coupling network 449 are described after that.

15 1) Transmission of Telephone Signals across Local Interface 404b (Figs. 33a, 33b)

When non-telephone signals transmitting on extended pair 405b do not have energy at voiceband frequencies, (e.g. the video signals represented in Fig. 23a or 23c) 20 signal separators 413 according to Fig. 29a are used, and the telephone signals communicating between local exchange 475 and telephone devices 414b are confined to the voiceband. Fig. 23a shows coupling network 437a which is an embodiment of network 437 used when telephone processor 25 424 is not included in signal separator 413b. In this case, the telephone signals are at voiceband.

Referring to Fig. 23a, voiceband telephone signals from extended pair 405b that transmit to interface 404b are blocked by high pass filter 472 in coupling network 437a, 30 passing instead through low pass filter 442, which is designed to pass only energy at voiceband frequencies, in telephone signal processing section 470a. These signals continue on to local network 411b. (They are blocked from the alternative path by high pass filter 463.) 35 Transmission of telephone signals in the opposite direction traces the reverse path. Thus, an unbroken path for

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voiceband signals from telephone device 414b (Fig. 21a) to local exchange 475 is provided. Fig. 23b shows coupling network 437b and telephone signal processing section 470b, which are specific embodiments of network 437 and section 470. Section 470b processes telephone signals that transmit over extended pair 405b at frequencies above voiceband (e.g., at RF).

All signals from extended pair 405b are applied directly to coupler 437b. Coupler 437b matches the impedance of each of the five paths that converge at its ports. Coupler 437b also balances the signals transmitting from interface 404b onto extended pair 405b. Finally, coupler 437b allows all converging signals to flow through freely to the other ports, meaning that routing of signals through that coupler is determined by the surrounding filters. (An example of such a coupler is shown in Part I of this disclosure.)

Telephone signals transmitting over extended pair 405b at frequencies above voiceband that transmit to coupler 437b are routed to band pass filter 454 and are blocked on all other exiting paths by filters that pass different frequency bands. The signals passed by filter 454 continue on to telephone signal converter 452. Converter 452 converts these signals to voiceband and transmits them through low pass filter 455 to local network 411b where they communicate with telephone device 414b in the ordinary manner. High pass filter 463 blocks these signals from transmitting along the alternative path.

In the reverse direction, processor 452 receives telephone signals at voiceband from local network 411b via low pass filter 455. Processor 452 converts these signals to RF and passes them through filter 453 to coupler 437b. These signals transmit only onto extended pair 405b because they are blocked from the other paths (by filters 445, 438, and 454). This completes a two-way telephone communication

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link using RF between processor 452 and telephone signal processor 424 in signal separator 413b at transceiver/switch 400.

5 2) Transmission of Non-Telephone Signals from Extended Pair 405b to Local Network 411b

Referring again to Fig. 23a, non-telephone signals from extended pair 405b that transmit to coupling network 437a pass through high pass filter 472 to coupler 483. They are blocked from the alternative path by filter 442, 10 which passes only voiceband signals.

Coupler 483 matches the impedance of each of the three paths that converge at its ports. Coupler 483 also balances the signals transmitting from interface 404b onto extended pair 405b.

15 In one embodiment of coupler 483, all signals converging at its ports flow freely through to the other ports. This means that the routing of signals through couplers 483 is determined by the filters on the connecting paths. In an alternative embodiment of coupler 483, 20 isolation is provided between the two paths leading to local processor 439 (Fig. 30). This increases the separation provided at coupling network 483 by filters 445 and 438.

Referring to Fig. 33b, coupler 437b matches the 25 impedance of each of the paths that converge at its ports and balances the signals transmitting from interface 404b onto extended pair 405b. All signals converging at coupler 437b pass freely out the other ports, meaning that routing of signals through coupler 437b is determined by the 30 filters connected to its ports.

Non-telephone signals received from pair 405b that transmit to coupler 483 (in Fig. 33a) or coupler 437b (in Fig. 33b) exit on the path leading to filter 438 (Fig. 30). Filter 438 passes only energy at frequencies used by non- 35 telephone signals transmitted by transceiver/switch 400, allowing those signals to pass through to local processor

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439. The same signals are blocked along the path leading from network 437 by filter 445, which passes only energy at frequencies used by non-telephone signals transmitting towards transceiver/switch 400. (In Fig. 33b, non-
5 telephone signals received from extended pair 405b are also blocked from the two other paths by filters 453 and 454.) Thus, all non-telephone signals received from extended pair 405b are received by local processor 439.

After processing, local processor 439 transmits
10 these signals to filter 460, and they ultimately transmit onto local network 411b, as will be described below. To avoid interference with telephone communication on local network 411b, signals transmitted by processor 439 to filter 460 are always provided at frequencies above the
15 ordinary telephone voiceband.

One important function of processor 439 (and of local network interfaces 404) is to amplify non-telephone signals received from filter 438, relaying them onto local network 411b at a higher energy level, thereby increasing
20 the SNR at the input to the RF receivers connected to local networks 411. Without this increase, the attenuation in transmitting from transceiver/switch 400 may prevent signals from reaching the receive end with sufficient SNR.

Another function of processor 439 is to convert
25 signals from filter 438 to the waveform (i.e., the modulation method) and frequency at which they will transmit onto local network 411b. Changing the waveform and frequency can simplify the design of the RF receivers of these signals, e.g., video receivers 419 and transceiver
30 491c. This is especially true if video is transmitted over pair 405b in FM form, or if the video signals transmitted by interface 404b onto local network 411b must coordinate with video signals transmitting locally, e.g., from video transmitters 417b to video receiver 419b. (Choosing
35 waveforms for various video signals transmitting across a

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local network and arranging their frequency bands to simplify receiver design is thoroughly discussed in Part II of this disclosure.) Various embodiments of processor 439, some of which perform frequency and waveform conversion, 5 all of which perform amplification, are given below.

Additional details of the routing of signals transmitting from processor 439 to local network 411b are now described. Filter 460 blocks energy at all frequencies except those used by signals fed to that filter from 10 processor 439. The signals passed by filter 460 transmit to coupling network 449.

Coupling network 449 serves as a junction for signals converging from three paths. Signals flow freely through this junction, exiting each of the opposite two 15 paths. Thus, filters 460, 461, and 463 determine the routing of the signals at coupling network 449.

Signals transmitting to coupling network 449 from filter 460 exit through the port leading to high pass filter 463. That filter blocks only voiceband signals, 20 allowing the signals from processor 439 to pass through onto local network 411b. Filter 455 in telephone signal processor section 470b (Fig. 33b) blocks signals from processor 439 from transmitting along the alternative path. Filter 442 in telephone signal processor section 470a (Fig. 25 33a) performs a similar function. Because it is a low-pass filter, filter 442 also suppresses the energy of transients and harmonics of voiceband signals originating at telephone device 414b (or other telephone devices connected to local network 411b) from transmitting onto extended pair 405b. 30 Because these may contain significant energy at higher frequencies, they can ordinarily cause interference with the RF signals communicating over that pair. The low pass filters that connect between devices 414 and the local networks 411 can also suppress these harmonics.

35 In addition to serving as a junction, coupling

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network 449 matches the impedance of the wiring of local network 411b to the circuitry internal to interface 404b. It also balances RF signals flowing from processor 439 onto local network 411b, and unbalances RF signals flowing in 5 the opposite direction. These functions tend to minimize radiation and increase the efficiency of the transfer of RF energy between local network 411b and interface 404b.

Referring also to Fig. 28, the following example shows how signals from extended pair 405a are coupled by 10 local network interface 404a onto local network 411a. Video signals U and V are fed onto extended pair 405a by signal separator 413a in transceiver/switch 400. Signal U is amplitude modulated in the 1-6 Mhz band, while signal V is frequency modulated in the 7 to 22 Mhz range. At local 15 network interface 404a, these signals transmit to network 437, and exit towards filter 438. (They are blocked from the other paths by the surrounding filters.) Signals U and V pass through filter 438 and are received by processor 439. Processor 439 demodulates video signal V, and 20 remodulates it using AM between the frequencies 24-30 Mhz at a signal level of 40dB mV. In parallel with this process, processor 439 demodulates video signal U and remodulates it using AM between the frequencies 12-18 Mhz and at a signal level of 40dB mV. These signals are 25 combined onto a single conductive path and fed through filter 460 to coupling network 449. They pass through that network, exiting through filter 463 and onto local network 411a. Video receiver 419a recovers these signals from the network, and block converts them upwards by 164 Mhz, 30 providing them to television 492a at 176-182 Mhz (VHF channel 7) and 188-194 Mhz (VHF channel 9). (A design for a video receiver that performs such a conversion is given in Part II of this disclosure.) One of the detailed embodiments of processor 439 shown below includes import 35 processor 440b. That component is designed to conduct the

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processing required to perform the conversion of video signal U and video signal V used in this example.

3) Transmission of Non-Telephone Signals from Local Network 411b to Extended Pair 405b

5 Video transmitter 417b connects to local network 411b to transmit signals at frequencies above voiceband. Examples of these signals are ordinary video signals from video cameras, digital signals from computers, and control signals from infrared transmitters. These signals are
10 referred to as non-telephone signals because they are not meant to communicate to local exchange 475. Techniques that transmit these signals across networks such as local network 411b are described in U.S. Patent No. 5,010,399 and in Parts I and II of this disclosure.

15 Certain control signals transmitted by video receiver 419b are intended to communicate with master controller 415 in transceiver/switch 400. These signals indicate, among other things, which signals are to be recovered from communication line 402 and transmitted over
20 extended pair 405b to local network 411b. Master controller 415 can make these determinations because it controls certain other components in transceiver/switch 400, as described above.

Because many potential users are familiar with
25 issuing control signals using infrared transmitters, that is the preferred method of originating these control signals, e.g., issuing infrared signals from remote control transmitter 493b. Video receivers 419b detect these infrared patterns and convert them to voltage variations
30 that are applied to local network 411b and received by local network interface 404b. That component relays the control signals across extended pair 405b to transceiver/switch 400 where it is received, as described above, by control signal processor 420.

35 Referring to Fig. 30, non-telephone signals fed to local network 411b for transmission to transceiver/switch

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400, are blocked by a high impedance at telephone signal processing section 470. (In the embodiment of section 470b, this impedance is supplied by low pass filter 455. In the embodiment of section 470a, this impedance is 5 supplied by low pass filter 442.) Because these signals are expressed in RF, however, they pass through high pass filter 463 to coupling network 449. These signals will exit that network towards filter 461, but will be blocked from the other exit by filter 460. (As described above, 10 filter 460 only allows energy used by signals transmitting from processor 439 to pass.) Thus, signals from video transmitter 417b will pass through filter 461 to processor 439.

Among the signals received from filter 461, those 15 intended for transmission to communication line 402 are converted by processor 439 to the waveform, frequency, and amplitude at which they will be fed to extended pair 405b. The relationship between these characteristics and the reliability of communication over extended pair 405b was 20 described above. Processor 439 feeds the converted signals through filter 445. The signals are then forced by the filtering (i.e., blocked by filters 438 and 442) through coupling network 437 and onto the corresponding extended pair 405b.

25 In some embodiments, signals recovered by processor 439 from local network 411b are processed and retransmitted onto that network. Such a procedure, and its attendant advantages, is described in Part II of this disclosure. That procedure is included as an option of the 30 communication system described herein because local network interfaces 404 provide a natural place to implement such a retransmission process. A specific embodiment of processor 439 that retransmits signals back onto local network 411b is described below.

35 Referring also to Fig. 28, the following is an

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example of transmission of signals from local network 411b through processor 439 to extended pair 405b. Video transmitter 417b receives video signal W at baseband from video camera 494b, amplitude modulates it between 6-12 Mhz, 5 and feeds it onto local network 411b where it transmits to filter 463 in local network interface 404b. Being blocked by low pass filter 455 (or by filter 442 when the embodiment shown in Fig. 33a applies) and filter 460, signal W transmits through high pass filter 463, coupling 10 network 449 and filter 461 to processor 439. Processor 439 converts video signal W to an FM signal between 24-54 Mhz, and transmits it through filter 445 and coupling network 437 onto extended pair 405b. (The relatively wide bandwidth is advantageous because, being at relatively high 15 frequencies, the signal will suffer more attenuation and be received at a lower SNR. Increasing the bandwidth compensates for this by making the reception process more sensitive.)

Meanwhile, video receiver 419b detects control 20 signal B (Fig. 28) which is issued by the user with infrared remote control transmitter 493b. Video receiver 419b converts this signal to voltage variations within the .5 Mhz band centered at 23 Mhz, and feeds the signal onto local network 411b. Following the same route as video 25 signal W, control signal B transmits to processor 439. Processor 439 receives control signal B and video signal W combined on the same conductive path. After processing, control signal B is at a higher energy level. (Signal W is converted as described above.) The two signals are fed 30 through filter 445 to coupling network 437. Filtering at network 437 routes the combined signal onto extended pair 405b. One of the detailed embodiments of processor 439 shown below includes export processor 441b. That component is designed to conduct the processing of video signal W and 35 control signal B used in this example.

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It will be appreciated that the part of signal processor 439 that receives RF signals from pair 405b and the part that feeds signals onto pair 405b, together with coupling network 437 and filters 438, 445, and 442 comprise 5 a transceiver that performs two-way RF communication with a network of active twisted pair wiring, specifically, extended pair 405b. A complete description of the basic signal processing elements required of such a transceiver is given in Part I of this disclosure. The processing 10 implemented by components 439, 437, 445, 442, and 438 of this disclosure includes those elements.

It will further be appreciated that the part of signal processor 439 that receives RF signals from local network 411b and the part that feeds signals onto local 15 network 411b, together with coupling network 449 and filters 442, 460, 461, and 463 also comprise a transceiver that performs two-way RF communication with a network of active twisted pair wiring, specifically, local network 411b. A complete description of the basic signal 20 processing elements required of such a transceiver is also given in Part I of this disclosure. The processing implemented by components 449, 460, 442, 461, 463, and 439 of this disclosure includes those elements.

25 4) Details of Specific Embodiments of Local Processor 439 (Figs. 31a, 31b)

Fig. 31a shows processor 439a which is a specific embodiment of processor 439. In processor 439a, all of the non-telephone signals received from local network 411b are transmitted through filter 445 and onto extended pair 405b, 30 and all non-telephone signals received by that processor from extended pair 405b are transmitted through filter 460 and onto local network 411. This simplifies the design, enabling processor 439a to be separated into two independent processors. As is seen in Fig. 31a, non-35 telephone signals transmitting from extended pair 405b onto local network 411b transmit through import processor 440.

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Non-telephone signals transmitting in the other direction, from local network 411b to extended pair 405b, transmit through export processor 441.

Import processor 440 converts the signals it receives from extended pair 405b to the waveform, frequency, and signal level at which they are fed through filter 460, network 449, and high pass filter 463 onto local network 411b. Fig. 31b shows three different embodiments of import processor 440.

Processor 440a, which is shown at the top of Fig. 31b, does not alter the waveform or frequency of its input. Rather, processor 440a simply adjusts the signal energy to a selected level. Typically, this adjustment results in an amplitude increase, thereby increasing the SNR at the RF receivers connected to local network 411b.

Typical governmental regulations do not limit the total energy that can be radiated by a single device. Rather, each individual signal transmitted by an RF device faces limitations on the radiation it can generate. For this reason, transceiver/switch 400 feeds each signal to extended pairs 405 at energy levels that create radiation just below the legal limits. This will maximize the SNR at the opposite end of extended pairs 405. For the same reason, import processor 440a boosts the levels of the signals it receives back to these "maximums" before retransmission onto local network 411b.

Because signals at higher frequencies encounter more attenuation, they will be received at levels further below the maximum than lower frequency signals. Thus, import processor 440a provides a gain that increases with frequency. This is achieved by a two phase process. In the first phase, the same gain is imparted to signals at all frequencies by amplifier 499. In the second phase, filter 497 applies an attenuation to the signal that decreases with increasing frequency, thus providing an

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output signal whose gain increases with frequency. Although this two-phase process is described herein, other techniques that impart a "sloped gain" can be used.

To provide a device that can be used in a variety of 5 installations, processor 440a allows the overall gain and the slope of the gain to be adjusted. As shown in Fig. 31b, these adjustments are preferably manual. (Alternatively, the adjustments can be made automatically using suitable feedback techniques.) Manual means are 10 acceptable because the levels of signals received from transceiver/switch 400 are not likely to change, making an initial adjustment sufficient. Also, it is likely that local network interfaces 404 will be professionally installed, removing another reason for providing automatic 15 adjustment.

Processor 440b (shown in the center of Fig. 31b) is designed to receive multiple (two in the embodiment shown) signals from extended pair 405c. (Because they are recovered from a single pair, of course, each signal will 20 be confined within different frequency bands.) Processor 440b demodulates, basebands and then remodulates each signal, providing them at a specific waveform, frequency, and energy level.

Processor 440b is especially useful when the signals 25 transmitted over pairs 405 are FM video signals. If video signals transmit onto local networks 411 in FM form, video receivers 419 must convert them to AM because most ordinary televisions only receive AM signals. (Some receive unmodulated signals, none receive FM video signals.) 30 Referring to Fig. 28, processor 440b can implement the conversion that local network interface 404a performs on video signals U and V before those signals are transmitted onto local network 411a.

The functioning of processor 440b is as follows. 35 The combined signals are divided in power by splitter 430,

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transmitting to demodulators 431a and 431b. Each of those components basebands a different one of the signals. The basebanded signals transmit to modulator/amps 432a and 432b, respectively. These components convert their 5 basebanded signal to the new waveform, frequency band, and energy level, and feed them to coupler 433. (Fig. 31b shows the individual steps of the modulation and demodulation processes inside the blocks representing demodulator 431a and modulator 432a.) Coupler 433 recombines the signals, 10 which are expressed within non-overlapping frequency bands, providing them to filter 460 along the same conductive path.

Import processor 440c (shown at the bottom of Fig. 31b), is designed to block convert signals from one 15 frequency range to a second frequency range. Referring to Fig. 28, assume that in addition to video signal V transmitting between 1 and 6 Mhz, a second video signal (not shown in Fig. 28) is amplitude modulated between 6-12 Mhz and transmits across extended pair 405b. Both these 20 signals transmit to import processor 440c and are upshifted in block converter 434 by 60 Mhz, thereby converting them to frequency bands of 61 MHz-66 MHz (VHF channel 3) and 66 MHz-72 MHz (VHF channel 4), respectively. Because these channels are tunable by ordinary televisions, video 25 receiver 419b will not need to convert the signals before transmitting them to television 492b. The signals are amplified after conversion, then exit towards filter 460 and are applied to local network 411b. This block conversion can also enable the video signals to coordinate 30 (i.e., avoid interference) with video signals transmitting locally across local network 411b, i.e., between video transmitter 417b and video receiver 419b.

Import processor 440c includes sloped amplifier 498 and block converter 434. Sloped amplifier 498 performs a 35 process similar to that of import processor 440a. It

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amplifies the input, but imparts more gain to the higher frequencies because they have attenuated more during transmission across the associated one of extended pairs 405. The output of sloped amplifier 498 is fed to block 5 converter 434. As is seen in Fig. 31b, that component shifts the signal in frequency by an amount equal to the frequency of a local oscillator. In the example above, the shift is 60 Mhz. The resulting signal is passed through a filter, amplified, and transmitted to filter 460. (In the 10 example above, filter 460 would pass only the frequencies between 60-72 Mhz.) To allow import processor 440c to be used in a variety of installations, the gain of the amplifier in block converter 434 is manually adjustable, as is the slope of amplifier 498. (In practice, these 15 settings would be adjusted to provide all of the output signals at levels that generate radiation slightly below the governmental limit.)

Export processor 441 receives signals from local network 411b and converts them to the waveform, frequency, 20 and signal level at which they are fed, ultimately, to extended pair 405b. Two embodiments of export processor 441 are shown in Fig. 31c, and are now described.

Export processor 441a amplifies the level of the signal applied to it, providing these signals on output at 25 levels that will create radiation on the extended pair 405 just below the legal limits. As such, it must impart a higher gain to the higher frequency signals because they have suffered more attenuation in transmitting across network 411b. Thus, it works in a manner identical to 30 import processor 440a (Fig. 31b), and its components, amplifier 499' and sloped filter 497', correspond in function to amplifier 499 and sloped filter 497 of processor 440a.

Export processor 441b is designed to provide 35 frequency and/or waveform conversion for one of its input

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signals, and to simply adjust the energy level of the others. The signals received by export processor 441b pass to splitter 484, which directs the signals to both demodulator 457 and filter 482. Demodulator 457 selects 5 one of the signals for demodulation. The basebanded result is passed to modulator 456 which remodulates the signal, providing it with a different waveform, frequency, and energy level. (The typical modulation and demodulation steps are shown internal to the blocks representing 10 modulator 457 and demodulator 456.) Filter 482, meanwhile, filters out the signal selected by demodulator 457, passing the remaining signal or signals for amplitude adjustment by gain control 481 to a fixed level, typically resulting in a level increase. (Gain control 481 performs its 15 processing in a manner identical to the processing performed by export processor 441a and import processor 440a.) The output of gain control 481 and the output of modulator 456 (which are in different frequency bands) are then combined onto the same conductive path by coupler 465, 20 and passed to filter 445.

Referring to Fig. 28, an example of the processing conducted by export processor 441b is given. Video receiver 419b provides control signal B between 22.75-23.25 Mhz and feeds it onto local network 411b, and video 25 transmitter 417b feeds video signal W onto local network 411b, using amplitude modulation between 6-12 Mhz. At local network interface 404b, video signal W is selected and demodulated by demodulator 457, and then frequency modulated between 24-54 Mhz by modulator 456. Control 30 signal B, meanwhile, passes through filter 482 to gain control 481, which increases its energy level. These two signals are then joined by coupler 465 and fed onto extended pair 405b by other components of local network interface 404b.

35 5) An Embodiment of Local Processor 439 that
 Retransmits Signals Recovered from Local Network

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411b (Fig. 32)

As discussed above, Fig. 10 shows a general embodiment of processor 439. As can be seen from that figure, processor 439 receives signals from local network 411b and also transmits signals onto that network. (The signals transmitted onto local network 411b are either received from extended pair 405b, received from local network 411b, or they are generated internally.) In the more specific embodiments shown in Figs. 31a-31c, only those signals recovered from extended pair 405b are fed onto local network 411b. Processor 439b, shown in Fig. 32, is a different specific embodiment of processor 439, and is described in this section. In contrast to processor 439a, the signals transmitted onto local network 411b by processor 439b can come from two sources: 1) they can be signals recovered from extended pair 405b, or 2) they can be signals received from local network 411b.

There are several reasons to provide for both sources. One of the advantages is that it allows for certain simplifications and economies in design of the components that receive the video signals, i.e., video receivers 419. It also allows for modifications of the retransmitted signals to be applied by a single device, i.e., the device performing such retransmission. Such modifications can include superposition of textual information such as a clock, a channel display, etc.

These advantages are described in Part II of this disclosure, wherein a similar signal processing device, RF video processor 312, is described. That device recovers video signals from a network of telephone wiring, processes those signals, and retransmits them onto the same network. Processor 312 is slightly modified in this application to provide processor 439b. More precisely, RF/video processor 312, shown in Fig. 12 is modified and combined with master controller 316 of Part II of this disclosure to provide a

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specific embodiment of the following elements of this application: processor 439, filters 461, 460, 463, and coupling network 449.

To see how RF/video processor 312 is modified,
5 realize that two of the functions of processor 439, receiving signals from network 411b and transmitting them onto that network, are already part of processor 312. The other two functions, receiving signals from extended pair 405b and converting signals and feeding them through filter
10 445 and onto extended pair 405b, are provided in the following manner.

As described in Part II of this disclosure, signals output from graphical processors 329 are basebanded video signals, but they can also be basebanded signals of a
15 general nature. Any one of these outputs can be split, under control of master controller 316, and fed to processor 473. Processor 473 converts the signal to the waveform, frequency, and amplitude at which it will transmit across extended pair 405b. Finally, the signal is
20 fed through port 321 to filter 445. After passing through that filter, the signal follows the transmission path, described above, onto extended pair 405b.

As described earlier, signals received from extended pair 405b pass through filter 438. To feed these signals
25 to processor 312, a conductive path is provided between filter 438 and port 315. (In Part II of this disclosure, one intended function for port 315 was to input cable TV signals.) Thus, this simple connection, plus processor 473, are the only additions necessary to adapt processor
30 312 to perform all of the functions of processor 439.

Note that in the embodiment shown in Fig. 12, filter 461 is actually two separate filters, as is filter 460. Furthermore, each conductive path leading to and from those filters is actually composed of two separate parallel
35 paths. This separation is due to the fact that in this

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embodiment, processor 439 recognizes a separate class of signals and processes them differently.

The signals in the special class are those intended communicate with master controller 316, and also signals sent by controller 316 that are intended to control devices that receive signals from or transmit them to local network 411b. In particular, the control signal from infrared transmitters 493b are detected by video receiver 419b, converted to voltage, and fed onto network 411b. This signal passes through filter 334 to processor 330.

In the reverse direction, master controller 316 instructs control signal creation circuitry 338 to generate control signals and feed them through filter 336 (part of filter 460) onto local network 411b. These signals will be received by video transmitters 417 and converted to infrared signals that are broadcast into the environment where they can be detected by nearby infrared responsive devices, such as TV 492b. This communication process is described more fully in Part II of this disclosure.

20 L. Boosting Signal Power within a Wiring Closet (Fig. 34)

As discussed above, the twisted pairs providing telephone service to the units of an apartment building often converge in a room in the basement of such a building, providing a point of common access to a large number of units. Other "common points of access" often available in an apartment building are the wiring closets that are often located on every floor. These provide an intermediate point of convergence to the telephone wires of the units on that floor. Bundles of multiple twisted pair wires often lead from the basement location to the wiring closets.

Locating transceiver/switch 400 in the basement is an economical alternative because it frees one from the requirement of bringing communication line 402 to the

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wiring closet of each floor, and because one device embodying transceiver/switch 400 can suffice for the entire building. (Although this device will need to have more internal components, economies will be enjoyed in hardware, 5 maintenance, and installation.)

In very large apartment buildings, however, the distances may be such that extended pairs 405 will be relatively long for certain apartment units. As is described above, this increases the attenuation of 10 transmission, preventing the use of higher frequencies and limiting the number of signals that can transmit at a single time. One solution to this problem is to provide amplification of the signals at an intermediate points, such as in the wiring closets.

15 Amplification at an intermediate point is most useful if half of the signal attenuation occurs before amplification, and half occurs afterwards. It can be shown that this maximizes the SNR at the receive end. To see this, assume that amplifying a particular signal to 50dB 20 and applying it to telephone wiring creates EMF radiation just below the legal limits. Assume further that a given transmission path imparts 30dB of attenuation and that the noise level at the input to the amplifier and at the input to the receiver at the end of the path is 5dB mV. Assuming 25 the signal encounters the amplifier after 25dB of attenuation, the SNR at the amplifier input will be 20dB. Because the amplifier processes signal and noise in parallel, and both signal and noise attenuate in parallel during transmission to the receiver, the SNR will be no 30 higher than 20 dB at the input to the receiver.

Now assume that the amplifier is encountered after only 5dB of attenuation. The signal level at the amplifier output will still be 50dB mV but 25dB of attenuation is encountered in transmission to the receiver, making the 35 signal level 25dB mV at that point. Because the noise will

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again be at its 5dB mV minimum, the SNR will be 20dB.

By contrast, if amplification is applied after 15dB of attenuation, which is the "midpoint", the signal level at both the amplifier input and the receiver input will be 5 35dB mV, and the SNR at the receiver will be 30dB.

Often, signal loss is divided approximately evenly between the attenuation of transmission on extended pairs 405, and the attenuation cause by the splits in signal energy that occur at the junctions of local networks 411.

10 This is an important reason why local network interfaces 404 are useful. When transceiver/switch 400 is located on a telephone pole, for example, the initial signal level is often sufficient to provide a good SNR at each of local network interfaces 404, and the received signal is then 15 boosted to transmit across local networks 411 to present at a receiver 419 with adequate SNR.

The wiring configuration of most apartment buildings offers a similar opportunity. Specifically, amplification devices can be placed in the wiring closets to boost the 20 level of the signals transmitting in both directions between transceiver/switch 400 and local networks 411. As such, this booster serves the function of local network interfaces 404, being located in a wiring closet instead of being mounted on the an external wall of a house.

25 A major advantage of this location is that one electronic device can provide the hardware for several local networks 411 at the same time. This provides hardware, installation, and maintenance economies. (A disadvantage is that the wires from several local networks 30 411 are still close enough to make crosstalk an issue.)

Fig. 34 shows a design for wiring closet booster 504, which houses local network interfaces 404a, 404b, and 404c. A situation where local interfaces 404a-404c can be co-located can occur, for example, when the five local 35 networks 411 are located in different units in an apartment

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building, and the units of local networks 411a, 411b, and 411c are located on the same floor and served by the same wiring closet.

Only the details of local network interface 404b are 5 shown. Furthermore, it is seen that the signal processing in each of 404a, 404b, and 404c is independent and that they operate on different signals. It will be appreciated, however, that local interfaces 404a-404c can be serviced by the same power supply. This is one of the hardware 10 economies of including them in the same housing.

The embodiment of local network interface 404b shown in Fig. 34 is similar to that shown in Fig. 30. The only differences are that some of the components are replaced by components that represent more specific embodiments. 15 Specifically, coupling network 437a, telephone signal processing section 470a, and local processor 439a, represent coupling network 437, telephone signal processing section 470, and local processor 439. Internal to local processor 439a, import processor 440a represents import 20 processor 440, and export processor 441a represents export processor 441.

According to the descriptions, provided above, of the components that are shown in Fig. 34, telephone signals transmit at baseband through telephone signal processing 25 section 470a between extended pair 405b and network 411b. Also, non-telephone RF signals from transceiver/switch 400 transmit through coupling network 437a, filter 438, import processor 440a, filter 460, coupling network 449, and filter 463 onto local network 411b. In the opposite 30 direction, non-telephone RF signals transmit from local network 411b through filter 463, coupling network 449, filter 461, export processor 441a, filter 445, coupling network 437a and across extended pair 405b to transceiver/switch 400. Filters 460 and 445 are shown with 35 dashed lines because these filters may not be necessary if

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the directional multiplexing in coupling networks 437a and 449 provides strong isolation of transmission paths.

Important to booster 504 are import processor 440a and export processor 441a. These components amplify their 5 input signals, outputting the individual signals in the various frequency bands at the energy level at which the radiated energy they create is just below the legal limit. This maximizes the SNR of non-telephone signals received from local networks 411a-411c, and the SNR of non-telephone 10 signals received from transceiver/switch 400.

There may be applications for allowing for communication between local networks 411 by transmitting signals between the ones of local network interfaces 404 located together within wiring closet booster 504. This 15 function is contemplated within this disclosure but technology to achieve it is not specifically described.

M. Transmission of Compressed Digital Video Signals (Fig. 35)

As described above, NTSC video signals can be 20 digitized and compressed, without losing information content, so that the resultant digital bitstream has a data rate that is slow enough to be expressed as an analog waveform in a remarkably narrow channel. Specifically, the resulting waveform can be confined within channels less 25 than 4 Mhz wide, and can be accurately received with SNRs less than 30dB. Thus, video signals encoded in this manner are more amenable to transmission within the system disclosed herein than even FM video signals.

Transmission of digital signals between 30 transceiver/switch 400 and local networks 411 was described above. Conceptually, these components are sufficient to transmit a digital bitstream representing a video signal. That description, however, does not include the digitization and compression components that may be used to 35 convert the signal at the transmit end, and does not include the elements that may be used to reconstruct the

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signal so that it can be viewed at the receive end. Those components and the manner in which they coordinate with the other elements of this communication system are the subject of this section.

5 As mentioned earlier, electronics that digitize and compress analog NTSC video signals in real time are relatively expensive, as are the electronics that perform the subsequent reconstruction of the analog signal from the digital bitstream. The expense typically increases
10 dramatically with the compression ratio, so that a compression process that allows the resulting bitstream to be expressed in bandwidths less than 4 Mhz and minimum SNRs less than 30dB is relatively complex and costly.

As a result, transmission of compressed digital
15 video is comparatively less complex and expensive if the video signals on communication line 402 are already in this form (i.e. an analog waveform representing a compressed digital bitstream) when they are applied to transceiver/switch 400. Such a system can be very
20 economical in distribution of cable TV, where a group of video signals is to be made available for selection by a large number of subscribers. The economy arises from the fact that this single group of signals need be digitized and compressed only once -- at the headend of the cable
25 system.

Referring to Fig. 25a, signal distribution subsystem 403a can select digitized video signals from communication line 402 and to feed them onto extended pairs 405. Indeed, transmission of these signals is, as a practical matter, no
30 different than transmission of the digital signals described above.

Following is an example. Assume communication line 402 is a single coaxial cable that provides 60 channels of digital video signals, confined within adjacent 4 Mhz bands
35 that extend between 200 Mhz and 440 Mhz. These signals are

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received by interface 409 and transmitted directly to splitter 426' in subsystem 403a. (I.e., interface 409 does not block shift or otherwise process these signals.) Splitter 426' feeds the signals to each demodulator 426.

5 Under control of master controller 415, demodulator 426a basebands the channel between 204 MHz and 208 Mhz, and transmits it to switch 462a, which in turn applies this basebanded signal to modulator 410d. Modulator 410d remodulates the signal, using AM, to the frequencies 10 between 12 MHz-16 Mhz. Thus, the effect of this modulation/demodulation is simply to shift the signal to the new band. The output of modulator 410d is fed to switch 401, and that device directs the signal through signal separator 413b onto extended pair 405b.

15 If subsystem 403c (Fig. 25c) is provided instead of subsystem 403a, the processing and signal flow work similarly. In this case, RF processors 485 convert the selected signal to the channel between 12 MHz and 16 Mhz.

If local network interfaces 404 are provided, they 20 can receive the digital signals from extended pairs 405, amplify them, convert them in frequency, and retransmit them onto local networks 411, all using the techniques described above. If local network interfaces 404 are not provided, these are signals transmitted directly onto local 25 networks 411 confined within a channel whose bandwidth is the same as the original channel confining the digital signal.

Referring to Fig. 35, the digital signals transmitted onto local networks 411 are received by digital 30 video receiver 505. This device is not shown connected to any local network in Figs. 21a or 21b. It is shown connected to TV 492b and local network 411b, however, and it coordinates with the rest of the system components in the same manner as video receiver 419b.

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In a general sense, this receiver is identical to television transceiver 15, shown in Fig. 2 in U.S. Patent No. 5,010,399. Specifically, video processing circuitry 506 corresponds to RF converter 19, coupling network 513 5 corresponds to coupling network 18, and control signal processing circuitry 514 corresponds to control signal processing circuitry 17.

Video signals from local network 411b are blocked from telephone device 414b by the low pass filter and are 10 directed by coupling network 513 to video processing circuitry 506. Coupling network 513 and circuitry 514 function identically to their corresponding components in transceiver 15.

Like RF converter 19, video processing circuitry 506 15 converts the received video signal to a form that is tunable by ordinary televisions. The following process is used, however, because the signal is an analog representation of a bitstream that represents a video signal.

20 In the first stage of the processing, the video signal is basebanded in the ordinary fashion. The elements in Fig. 35 show the steps of this process: shifting to an intermediate channel by mixing with a local oscillator, filtering of the intermediate channel, and then 25 demodulation. Using the example above, the 16 MHz-20 Mhz signal may be shifted to the 40 MHz-44 Mhz band, filtered, and then detected, resulting in a basebanded signal. Alternatively, the "intermediate channel" can be fixed at 16 MHz-20 Mhz, removing the need for frequency shifting.

30 In the second stage, the basebanded analog signal is converted to a digital bitstream, which is decompressed in real time. In the classic procedure, a digital process reads the bitstream and uses that data to fill out a matrix of storage locations representing the pixels of the image. 35 This matrix is refreshed 60 times a second, the "refresh

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rate" of NTSC video. The actual NTSC signal is then created by scanning across the storage locations (conceptually, the pixels of a frame) just as a video camera creates a picture by scanning across a 5 photoconductive grid.

The third stage is the modulation stage. The newly recreated NTSC signal is passed to this stage at baseband. It is mixed using a local oscillator, creating an AM NTSC signal in the ordinary manner. This signal is passed to TV
10 492b.

Note that channel selection still takes place in the ordinary manner. Using the examples above, IR transmitter 493b issues infrared signals that are detected by the IR sensitive diode of receiver 505. These signals are 15 converted by circuitry 514 to, for example, a .5 Mhz signal centered at 23 Mhz. (This is the frequency used for communication of control signals in Fig. 28.) These signals are applied to local network 411b and transmit to master controller 415 using the circuitry and signals paths 20 described in the sections above. In response to this signal, controller 415 can instruct demodulator 426a to select a different channel from among the 60 available between 200 MHz-440 Mhz on communication line 402.

When FM communication techniques are not sufficient 25 due to the length of extended pairs 404 and the nature of local networks 411, communication of the video signals in compressed digital form is indicated, even if signals are provided by communication line 402 in analog form. In that event, digitization and compression are performed prior to 30 transmission onto extended pairs 405. This conversion can take place in signal distribution subsystem 403a.

Referring to Fig. 25a, the desired result can be achieved by replacing one of modulators 410 for every 35 digital video signal provided by processor 418. The new processors 410 are similar in that they receive a

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basebanded video signal and output an analog waveform confined within a particular channel at a signal level that creates radio energy just below the legal limits. The difference is that the waveform now represents a compressed 5 digital bitstream, which in turn represents the original NTSC signal.

The above description includes the components used to transmit digital video signals from transceiver/switch 400 to local networks 411. Similar techniques can be used 10 for transmission in the opposite direction but are not specifically described herein.

N. Transmission of Video Signals Across Computer Communication Networks with "Star" Configurations (Fig. 36)

15 As described in the summary section, in many office buildings, the telephone wiring is not the only network of twisted pair wiring that extends to each office and converges at a common point. Over the past several years, common communication networks that connect personal 20 computers, known as Local Area Networks or LANs, have begun to use twisted pair wiring for their conductive paths. In the typical configuration, a digital electronic device serves as the "hub" for such a system, and a separate twisted pair wire connects from the hub to each of the 25 computer nodes in a "star configuration". In this section, the techniques described for communication across wiring networks that conduct telephone communication are extended to provide the same communication capabilities across computer networks that used twisted pair wiring and adopt 30 such a "star" configuration.

To illustrate such a star configuration, one need only change a few of the elements of the setup shown in Fig. 21b. The result is shown in Fig. 36. One change is that PBX 500 is replaced by communications hub 519, which 35 is the digital device that serves as the "nerve center" of the communication system. Another change is that line 475'

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is not required. Finally, telephone devices 514 are replaced by computers 518, which are the devices that communicate across the network using the concepts described herein.

5 The only fundamental change required when the communication medium is provided by this new system is that the lower bound on the frequencies available for communication with line 402 (or for communication between the RF transmitters, receivers, and transceivers connected
10 to the local networks) will be higher. Specifically, the lower bound must be above the highest frequency used for communication between computers 518 and hub 519. For example, when the computer communication system follows the
15 10 Base T standard, which is the most popular standard for local area networks that use twisted pair wires, the computers communicate at frequencies up to 15 Mhz, and the lower bound must be above that above that frequency.

Following are the electronic changes that should be made to provide all of the functions discussed above:

- 20 1) The low pass filters connecting between computers 518 and local area networks 511 must have higher cutoff values. Specifically, the cutoff frequency must be high enough to pass the communication signals transmitting between hub 519 and computers 518.
- 25 2) The cutoff frequency of low pass filters 474 (Fig. 22) is increased in a similar fashion. The cutoff frequency of low pass filter 442 should also be increased if local network interfaces 404 are provided.
- 30 3) The cutoff frequency of hi-pass filter 451, which is part of signal separators 413 shown in Fig 9a, should be raised above the highest frequency used by computers 518. Thus, this filter will not pass some of the lower frequency signals it passed previously.
- 35 4) The spectral distributions shown in Fig. 23 will not be available if they overlap the frequencies used by the computer

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signals. Higher frequencies can be used.

5) The minimum frequencies suggested in Section C will also not be available if they overlap the frequencies used by the computer signals.

O. Preventing Unintended Reception and Control Signal Confusion

The problem of energy from one extended pair crossing over to a second pair and causing interference with video signals was described above. One proposed solution was to lower the susceptibility to interference by encoding the signals using frequency modulation. Susceptibility would be reduced because of the low "capture ratios" exhibited by FM receivers.

15 A second problem is caused by energy crossover, however, that may not be adequately addressed by low "capture ratios." This problem is one that arises when the second pair is not being used to conduct video signals, and the energy crossing onto that wire is sufficient to allow 20 reception of the signal on the local network to which the second extended pair connects. A related problem is where the control signal transmitted onto one extended pair crosses over to a second pair, causing transceiver/switch 400 to react as if a control signal had genuinely been 25 applied to the second pair.

The proposed solution is to ensure that a signal always transmits onto each of the extended pairs in a bundle within each of the channels used for transmission, whether or not a genuine signal is intended for conduction 30 at that channel. A convenient way of doing this is to transmit the unmodulated carrier for every channel onto those wire pairs that are not intended to conduct a signal at that channel. Similarly, continuously transmitting the carrier of the control signal can solve the related problem 35 of control signal "confusion."

Following is an example using the signals listed in Fig. 28. Note that video signal V is transmitted onto

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extended pair 405a between the frequencies of 7 Mhz and 22 Mhz. This signal is created by frequency modulating a carrier of 14.5 Mhz, and is received by local network interface 404a and relayed onto network 411a. Assuming 5 that signal V was not transmitted onto extended pairs 405b and 405c but crosses over onto pairs 405b and 405c, there would be a danger that the crossover signal V could be received by local network interfaces 404b and 404c. (Fig. 28 shows that signal V is indeed transmitted to networks 10 411b and 411c between 1-6 Mhz, but we will ignore that fact for the purposes of this example.) The proposed solution is to transmit the unmodulated 14.5 Mhz carrier onto extended pairs 405b and 405c, lowering the SNR of the crossover video signal V received by local network 15 interfaces 404b and 404c below acceptable levels.

Continuing the example, users at network 411a may issue infrared control signals that are transmitted over extended pair 405a by modulating a carrier with a fundamental frequency of 23 Mhz. Theoretically, these 20 signals can crossover onto extended pairs 405b and 405c, incorrectly exciting control signal processor 420 in transceiver/switch 400. The proposed solution is to have video receivers 419b and 419c continuously feed their 23 Mhz carrier, unmodulated, onto networks 411b and 411c (from 25 which they are relayed onto extended pairs 405b and 405c by local network interfaces 404b and 404c.)

Still other embodiments are within the scope of the following claims.

CLAIMS

1. A system for communicating video signals between a source of said signals and a destination of said video signals, said system comprising:
 - 5 a transmitter coupled between said source and a first location on a telephone link that carries voice signals from at least one telephone connected to said link, said transmitter including:
 - circuitry for frequency modulating said video signals from said source in a selected frequency band that exceeds frequencies of said voice signals, and
 - circuitry for coupling said frequency modulated signals onto said telephone link; and
 - a receiver coupled between a second location on said telephone link and said destination, said receiver including:
 - circuitry for recovering said frequency modulated signals from said telephone link,
 - circuitry for demodulating said frequency modulated signals to reproduce said video signals, and
 - circuitry for applying said reproduced video signals to said destination.
2. The system of claim 1 wherein said circuitry for coupling includes circuitry for impeding said voice signals from being coupled from said telephone link to said frequency modulation circuitry.
3. The system of claim 2 wherein said circuitry for impeding includes a filter for passing said frequency modulated signals and substantially rejecting said voice signals.
4. The system of claim 1 wherein said circuitry for recovering includes circuitry for impeding said voice

signals from being coupled from said telephone link to said frequency demodulation circuitry.

5. The system of claim 4 wherein said circuitry for impeding includes a filter for passing said frequency modulated signals and substantially rejecting said voice signals.

6. The system of claim 1 further comprising circuitry, coupled between said telephone and said telephone link, for impeding said frequency modulated signals from being coupled from said telephone link to said telephone.

7. The system of claim 6 wherein said circuitry for impeding includes a filter for passing said voice signals and substantially rejecting said frequency modulated signals.

8. The system of claim 1 wherein said destination includes a television for displaying said video signals from said receiver.

9. A transmitter adapted to be coupled between a source of video signals and a first location on a telephone link that carries voice signals from at least one telephone connected to said link, said transmitter being adapted for use with a receiver coupled between a second location on said telephone link and a destination of said video signals so that signals transmitted by said transmitter on said telephone link can be recovered by said receiver and applied to said destination, said transmitter including circuitry for frequency modulating said video signals from said source in a selected frequency band that exceeds frequencies of said voice signals, and

circuitry for coupling said frequency modulated signals onto said telephone link for transmission to said receiver.

10. The transmitter of claim 9 further comprising
5 circuitry for connecting a second telephone to said telephone link at said first location,

circuitry for impeding voice signals from being coupled from said second telephone to said frequency modulation circuitry, and

10 circuitry, coupled between said second telephone and said telephone link, for impeding said frequency modulated signals from being coupled to said second telephone.

11. The transmitter of claim 9 wherein said receiver includes

15 circuitry for recovering said frequency modulated signals from said telephone link at said second location,
circuitry for demodulating said frequency modulated signals to reproduce said video signals, and
circuitry for applying said reproduced video signals
20 to said destination.

12. A receiver adapted to be coupled between a location on a telephone link that carries voice signals from at least one telephone connected to said link and a destination of video signals, said receiver being adapted
25 for use with a transmitter coupled between another location on said telephone link and a source of said video signals, the transmitter frequency modulating said video signals and transmitting the frequency modulated signals on said telephone link, said receiver including

30 circuitry for recovering said frequency modulated signals from said telephone link,
circuitry for demodulating said frequency modulated

signals to reproduce said video signals, and
circuitry for applying said reproduced video signals
to said destination.

13. The receiver of claim 12 further comprising
5 circuitry for connecting a second telephone to said
telephone link at said location,

circuitry for impeding voice signals from being
coupled from said second telephone to said frequency
demodulation circuitry, and

10 circuitry, coupled between said second telephone and
said telephone link, for impeding said frequency modulated
signals from being coupled to said second telephone.

14. The receiver of claim 12 wherein said
transmitter includes

15 circuitry for performing said frequency modulation
in a selected frequency band that exceeds frequencies of
said voice signals, and

circuitry for coupling said frequency modulated
signals onto said telephone link.

20 15. A system for communicating audio signals
between a source that produces said signals at a
predetermined fidelity level and a destination of said
signals, said system comprising:

25 a transmitter coupled between said source and a
first location on a telephone link that carries voice
signals from at least one telephone connected to said link,
said transmitter including

30 circuitry for converting said audio signals to
a frequency band that exceeds frequencies of said voice
signals in a manner that substantially preserves said
predetermined fidelity level,

circuitry for coupling said converted signals

onto said telephone link; and

a receiver coupled between a second location on said telephone link and said destination, said receiver including:

5 circuitry for recovering said converted signals from said telephone link,

circuitry for reconverting said recovered signals from said frequency band to audio signals in a manner that substantially preserves said predetermined
10 fidelity level, and

circuitry for applying said audio signals to said destination.

16. The system of claim 15 wherein
said circuitry for converting comprises circuitry
15 for modulating said audio signals in said frequency band,
and

said circuitry for reconverting includes circuitry for demodulating said signals recovered from said telephone link from said frequency band to reproduce said audio
20 signals.

17. The system of claim 15 wherein said source produces said audio signals in a pair of channels and said destination is adapted to receive said audio signals in said pair of channels,

25 said transmitter including circuitry for modulating the audio signals in each of said channels in said frequency band, and circuitry for coupling said modulated signals from each channel onto said telephone link, and

30 said receiver including circuitry for demodulating said signals recovered from said telephone link and reproducing said audio signals in each of said channels, and circuitry for coupling each channel of said audio signals to said destination.

18. The system of claim 17 wherein
said circuitry for modulating is adapted to modulate
said video signals in said channels in different portions
of said frequency band, and

5 said receiver includes circuitry for separating said
recovered signals into said channels each of which
corresponds to one of said portions of said frequency band,
and circuitry for demodulating said recovered signals in
each said channel.

10 19. The system of claim 18 wherein said receiver
further comprises circuitry for controlling the amplitude
of the recovered signals in each of said channels.

20. The system of claim 16 wherein said modulating
includes frequency modulation.

15 21. The system of claim 16 wherein said modulating
includes amplitude modulation.

22. The system of claim 15 further adapted for use
with a source of video signals and a destination of said
video signals, wherein

20 said transmitter is also adapted to be coupled
between said source of said video signals and said first
location on a telephone link said transmitter further
including

25 circuitry for converting said video signals to
a frequency band different from said frequency band for
said converted audio signals and that exceeds frequencies
of said voice signals, and

30 circuitry for coupling said converted video
signals onto said telephone link with said converted audio
signals; and

 said receiver is also coupled between said second

location on said telephone link and said destination of said video signals, said receiver further including circuitry for recovering said converted video signals from said telephone link,

- 5 circuitry for reproducing said video signals from said recovered signals, and
 circuitry for applying said reproduced video signals to said destination thereof.

23. The system of claim 22 wherein said transmitter
10 further comprises

 circuitry for impeding said converted video signals from being coupled to said circuitry for converting said audio signals, and

15 circuitry for impeding said converted audio signals from being coupled to said circuitry for converting said video signals.

24. The system of claim 22 wherein said receiver
further comprises

20 circuitry for impeding said recovered video signals from being coupled to said circuitry for reconverting said audio signals, and

 circuitry for impeding said recovered audio signals from being coupled to said circuitry for reconverting said video signals.

25. 25. A system for communicating video signals and audio signals between respective sources that produces said signals and respective destinations of said signals, and for communicating control signals between a source thereof and at least one of said video source and said audio source, said system comprising:

A. a transmitter coupled between said video source and said audio source and a first location on a telephone

- link that carries voice signals from at least one telephone connected to said link, said transmitter including
- video processing circuitry for converting said video signals to a first frequency band that exceeds frequencies of said voice signals,
- audio processing circuitry for converting said audio signals to a second, different frequency band that exceeds frequencies of said voice signals,
- circuitry for coupling said converted video signals and said converted audio signals onto said telephone link;
- B. a receiver coupled between a second location on said telephone link and said video destination, said audio destination, and said source of said control signals, said receiver including:
- circuitry for recovering said converted video signals from said telephone link and reproducing said video signals therefrom,
- circuitry for recovering said converted audio signals from said telephone link and reproducing said audio signals therefrom,
- circuitry for applying said reproduced video signals to said destination thereof and for applying said reproduced audio signals to said destination thereof,
- 25 circuitry for receiving said control signals from said source,
- circuitry for converting said control signals to a third frequency band that is different than said first frequency band and said second frequency band and that exceeds frequencies of said voice signals, and
- circuitry for coupling said converted control signals onto said telephone link for transmission to said transmitter;
- C. said transmitter further comprising
- 35 circuitry for recovering said converted control

signals from said telephone link and reproducing said control signals therefrom, and

5 circuitry for applying said reproduced control signals to said at least one of said video source and said audio source.

26. The system of claim 25 wherein said source of said control signals radiates said control signals as infrared signals,

10 said circuitry for converting said control signals including circuitry for producing electrical signals that correspond to said infrared signals in said third frequency band,

15 said circuitry for reproducing said control signals including circuitry for generating infrared signals that correspond to said electrical signals, and

said circuitry for applying said reproduced control signals including circuitry for radiating said generated infrared signals for reception by said video source and said audio source.

20 27. The system of claim 25 wherein said transmitter further comprises

a filter disposed between said video processing circuitry and said coupling circuitry for passing substantially only signals in said first frequency band 25 therebetween,

a filter disposed between said audio processing circuitry and said coupling circuitry for passing substantially only signals in said second frequency band therebetween, and

30 a filter disposed between said circuitry for recovering said converted control signals from said telephone link and said circuitry for applying said reproduced control signals to said sources for passing

substantially only signals in said third frequency band therebetween.

28. The system of claim 25 wherein
said circuitry for recovering said converted video
5 signals in said receiver comprises a filter for passing
substantially only signals in said first frequency band,
said circuitry for recovering said converted audio
signals in said receiver comprises a filter for passing
substantially only signals in said second frequency band,
10 and

said receiver further comprises a filter, disposed
between said circuitry for converting said control signals
to said third frequency band and said circuitry for
applying said converted control signals to said telephone
15 link, for passing substantially only signals in said third
frequency band.

29. The system of claim 25 further comprising
circuitry, coupled between said telephone and said
telephone link, for impeding signals in said first, second,
20 and third frequency bands from being coupled from said
telephone link to said telephone.

30. Apparatus for recovering a television signal
sent by a source thereof over a communication link and
applying the recovered television signal to a television
25 receiver, said television signal including an amplitude
modulated video component and an accompanying frequency
modulated audio component, said apparatus comprising
circuitry for recovering said television signal from
said communication link, the recovered television signal
30 possibly including noise that causes variations in at least
the amplitude of said amplitude modulated audio component,
circuitry for measuring said variations in said

amplitude of said audio component of said recovered television signal as an indication of the level of said noise in said video component, and using said measured variations to reduce said level of noise in said recovered
5 television signal, and

circuitry for applying said recovered television signal with the reduced noise level to said television receiver.

31. The apparatus of claim 30 wherein said
10 measuring circuitry includes circuitry for separating said audio component from said video component.

32. The apparatus of claim 31 wherein said audio component has a carrier frequency that is outside of a frequency band that includes said video component, said
15 separating circuitry including a filter that substantially blocks frequencies in said frequency band.

33. The apparatus of claim 31 wherein said measuring circuitry further comprises circuitry for averaging the amplitude of said audio component over a
20 selected time period.

41. A system for video signal communication between a source of said video signal located outside of a unit and a destination of said video signal disposed within said unit, said system comprising:

25 an interface coupled to said source and to a telephone link that is disposed within said unit and carries voice signals from at least one telephone connected to said link, said interface including
circuitry for receiving said video signal from
30 said source, and

circuitry for transmitting said received video signal onto said telephone link in a selected frequency range that is different from frequencies at which said voice signals are carried on said telephone link to cause 5 said video signal to be coupled to a receiver connected to said telephone link, said receiver being adapted to recover said video signal from said telephone link and apply said recovered video signal to said destination.

42. The system of claim 41 wherein said source is 10 a cable that is linked to said unit and that carries a plurality of video signals, said transmitting circuitry further comprising

circuitry for selecting at least one of said video signals in response to control information from a user of 15 said destination and transmitting said selected video signal onto said telephone link for recovery by said receiver and application to said destination.

43. The system of claim 42 wherein said unit includes a plurality of destinations each of which is 20 connected to said telephone link by a said receiver, said selecting circuitry being adapted to respond to control information from users of said plurality of destinations by selecting one or more of said video signals and transmitting said selected video signals onto said 25 telephone link at different frequencies within said selected frequency range for recovery by said receivers and application to said destinations.

44. The system of claim 42 wherein said destination is a television is adapted to receive said selected video 30 signal in a predetermined frequency band, said transmitting circuitry further including

circuitry for transmitting said selected video

signal onto said telephone link at a band within said selected frequency range that allows said receiver to apply said recovered video signal to said television in said predetermined frequency band.

5 45. The system of claim 42 wherein said cable includes an electrical conductor for carrying said video signals.

10 46. The system of claim 41 wherein said interface is connected to a telephone line that is connected to said telephone link and extends outside of said unit, said interface including circuitry for passing said voice signals between said telephone link and said telephone line and preventing said video signal from being applied to said telephone line.

15 47. The system of claim 41 wherein said voice signals are carried on said telephone link at voiceband frequencies, and said selected frequency range exceeds said voiceband frequencies.

20 48. The system of claim 41 wherein said unit is a residence.

49. A method for video signal communication between a source of said video signal located outside of a unit and a destination of said signal disposed within said unit, said method comprising:

25 receiving said video signal from said source at an interface coupled to said source and to a telephone link that is disposed within said unit and carries voice signals from at least one telephone connected to said link, and
transmitting said received video signal onto said
30 telephone link in a selected frequency range that is

different from frequencies at which said voice signals are carried on said telephone link to cause said video signal to be coupled to a receiver connected to said telephone link, said receiver being adapted to recover said video signal from said telephone link and apply said recovered video signal to said destination.

50. A system for video signal communication, said system comprising:

an interface coupled to a telephone link that carries voice signals from at least one telephone connected to said link, said interface including

circuitry for receiving said video signal from a source thereof that includes a transmitter adapted to apply said video signal onto said telephone link in a first selected frequency range that is different from frequencies at which said voice signals are carried on said telephone link, and

circuitry for retransmitting said received video signal onto said telephone link in a second selected frequency range that is different from said first frequency range and from said frequencies at which said voice signals are carried on said telephone link to cause said retransmitted video signal to be coupled to a receiver connected to said telephone link, said receiver being adapted to recover said video signal from said telephone link and apply said recovered video signal to said destination.

51. The system of claim 50 wherein at least said destination is disposed within a unit and said interface further comprises

circuitry for receiving a second video signal from a second source located external to said unit, and circuitry for transmitting said second video signal

onto said telephone link in a third selected frequency range that is different from said first and second frequency ranges and from said frequencies at which said voice signals are carried on said telephone link to cause 5 said second video signal to be coupled to said receiver via said telephone link, said receiver being further adapted to recover said second video signal from said telephone link and apply said recovered second video signal to said destination.

10 52. The system of claim 51 wherein the first mentioned source is also disposed in said unit.

53. The system of claim 52 wherein said unit is a residence.

54. A method for video signal communication between 15 a source thereof and a destination, comprising:

receiving said video signal at an interface from said source via a telephone link that also carries voice signals from at least one telephone connected to said link, said source including a transmitter that is adapted to 20 apply said video signal onto said telephone link in a first selected frequency range that is different from frequencies at which said voice signals are carried on said telephone link, and

retransmitting said received video signal from said 25 interface onto said telephone link in a second selected frequency range that is different from said first frequency range and from said frequencies at which said voice signals are carried on said telephone link to cause said retransmitted video signal to be coupled to a receiver 30 connected to said telephone link, said receiver being adapted to recover said video signal from said telephone link and apply said recovered video signal to said

destination.

55. A system for video signal communication between a source of said video signal located outside of a unit and a destination of said video signal disposed within said 5 unit, said system comprising:

an interface coupled to said source via a cable that is linked to said unit and that carries a plurality of video signals, said interface also being coupled to a telephone link that is disposed within said unit and 10 carries voice signals from at least one telephone connected to said link, said interface including

circuitry for receiving said video signals from said source on said cable,

15 circuitry for selecting at least one of said video signals in response to control information from a user of said destination

20 circuitry for transmitting said selected video signal onto said telephone link in a selected frequency range that is different from frequencies at which said voice signals are carried on said telephone link to cause said selected video signal to be coupled to a receiver connected to said telephone link, said receiver being adapted to recover said selected video signal from said telephone link and apply said recovered video signal to 25 said destination.

56. The system of claim 55 wherein said destination is a television is adapted to receive said selected video signal in a predetermined frequency band, said transmitting circuitry further including

30 circuitry for transmitting said selected video signal onto said telephone link at a band within said selected frequency range that allows said receiver to apply said recovered video signal to said television in said

predetermined frequency band.

57. The system of claim 55 wherein said interface is connected to a telephone line that is connected to said telephone link and extends outside of said unit, said interface including circuitry for passing said voice signals between said telephone link and said telephone line and preventing said video signal from being applied to said telephone line.

58. The system of claim 55 wherein said voice signals are carried on said telephone link at voiceband frequencies, and said selected frequency range exceeds said voiceband frequencies.

59. The system of claim 55 wherein said unit is a residence.

15 60. A method for video signal communication between a source of said video signal located outside of a unit and a destination of said video signal disposed within said unit, said method comprising:

20 receiving said video signals from said source at an interface coupled to said source via a cable that is linked to said unit and that carries a plurality of video signals, said interface also being coupled to a telephone link that is disposed within said unit and carries voice signals from at least one telephone connected to said link,

25 selecting at least one of said video signals in response to control information from a user of said destination, and

30 transmitting said selected video signal onto said telephone link in a selected frequency range that is different from frequencies at which said voice signals are carried on said telephone link to cause said selected video

signal to be coupled to a receiver connected to said telephone link, said receiver being adapted to recover said selected video signal from said telephone link and apply said recovered video signal to said destination.

5 61. A system for video signal communication between a source thereof and a plurality of units that include destinations of said video signal, said system comprising an interface coupled to said source and to telephone lines, each of said telephone lines serving at least one of
10 said units and carrying voice signals to and from one or more telephones coupled to said line at said unit, said interface including

 circuitry for receiving said video signal from said source, and

15 circuitry for transmitting said received video signal onto at least one of said telephone lines in a selected frequency range that is different from frequencies at which said voice signals are carried on said one telephone line to cause said video signal to be coupled to
20 a receiver connected to said telephone line at the unit served by said line, said receiver being adapted to recover said video signal from said telephone line and apply said recovered video signal to one or more of said destinations at said unit.

25 62. The system of claim 1 wherein said source is a cable that is linked to said interface and that carries a plurality of video signals, said transmitting circuitry further comprising

 circuitry for selecting at least one of said video signals in response to control information from a user at
30 one of units and transmitting said selected video signal onto said telephone line that serves said unit for recovery by said receiver and application to said destination.

63. The system of claim 62 wherein at least one of said units includes a plurality of destinations each of which is connected to said telephone line by a said receiver, said selecting circuitry being adapted to respond 5 to control information from users of said plurality of destinations at said unit by selecting one or more of said video signals and transmitting said selected video signals onto said telephone line that serves said unit at different frequencies within said selected frequency range for 10 recovery by said receivers and application to said destinations.

64. The system of claim 61 wherein said source is a cable that is linked to said interface and that carries a plurality of video signals, said transmitting circuitry 15 further comprising

circuitry for selecting one or more of said video signals in response to control information from users at a plurality of said units and transmitting said selected video signals onto said telephone lines that serve said 20 units for recovery by each said receiver and application to each said destination.

65. The system of claim 64 wherein said selecting circuitry is adapted to transmit a selected one of said video signals onto a plurality of said telephone lines.

25 66. The system of claim 65 wherein said selecting circuitry is adapted to transmit said selected video signal onto said plurality of said telephone lines at different frequencies.

67. The system of claim 61 wherein at least one of 30 said units includes an internal telephone link to which a said receiver and at least one telephone is connected, said

internal telephone link being connected to said telephone line that serves said unit.

68. The system of claim 67 further comprising a local interface connected between said telephone line and 5 said telephone link of said at least one unit, said local interface including

circuitry for receiving said video signal from said telephone line, and

10 circuitry for amplifying said received video signal and coupling said amplified video signal onto said internal telephone link for recovery by said receiver.

69. The system of claim 68 wherein said at least one unit includes a source of a second video signal that includes a transmitter adapted to apply said second video 15 signal onto said internal telephone link in a second selected frequency range that is different said frequency range selected by said interface and from frequencies at which said voice signals are carried on said telephone link, said local interface further comprising

20 circuitry for receiving said second video signal from said internal telephone link, and

circuitry for amplifying said received second video signal and coupling said amplified video signal onto said telephone line that serves said unit to cause said second 25 video signal to be coupled to said interface.

70. The system of claim 69 wherein said interface further comprises

circuitry for receiving said second video signal from said telephone line, and

30 circuitry for transmitting said received second video signal to said source.

71. The system of claim 1 wherein said interface is coupled between said telephone lines and corresponding public telephone lines that serve said units, said public telephone lines carrying said voice signals at voiceband frequencies, said interface further comprising circuitry for coupling said voice signals between each said public telephone line and each said telephone line at said voiceband frequencies, said selected frequency range exceeding said voiceband frequencies.

10 72. The system of claim 1 wherein said interface is coupled between said telephone lines and corresponding public telephone lines that serve said units, said public telephone lines carrying said voice signals at voiceband frequencies, said interface further comprising
15 circuitry for converting said voice signals on least one of said public telephone lines to a second frequency range that exceeds voiceband frequencies and coupling said converted voice signals onto said corresponding telephone line, at least a portion of said selected frequency range
20 including said voiceband frequencies.

73. The system of claim 12 wherein said at least one of said units includes an internal telephone link to which a said receiver and at least one telephone is connected, said internal telephone link being connected to
25 said telephone line that serves said unit, and further comprising a local interface connected between said telephone line and said telephone link of said at least one unit, said local interface including

 circuitry for reconverting said voice signals
30 received from said telephone line to said voiceband frequencies and coupling said reconverted voice signals onto said internal telephone link, and
 circuitry for changing the frequency of said video

signal received from said telephone line to a frequency band that exceeds said voiceband frequencies and then coupling video signal onto said internal telephone link.

74. The system of claim 1 wherein at least some of 5 said units are residences.

75. The system of claim 14 wherein at least some of said residences are individual houses.

76. The system of claim 14 wherein at least some of said residences are apartment units in a building.

10 77. The system of claim 1 wherein at least some of said units are offices in an office building.

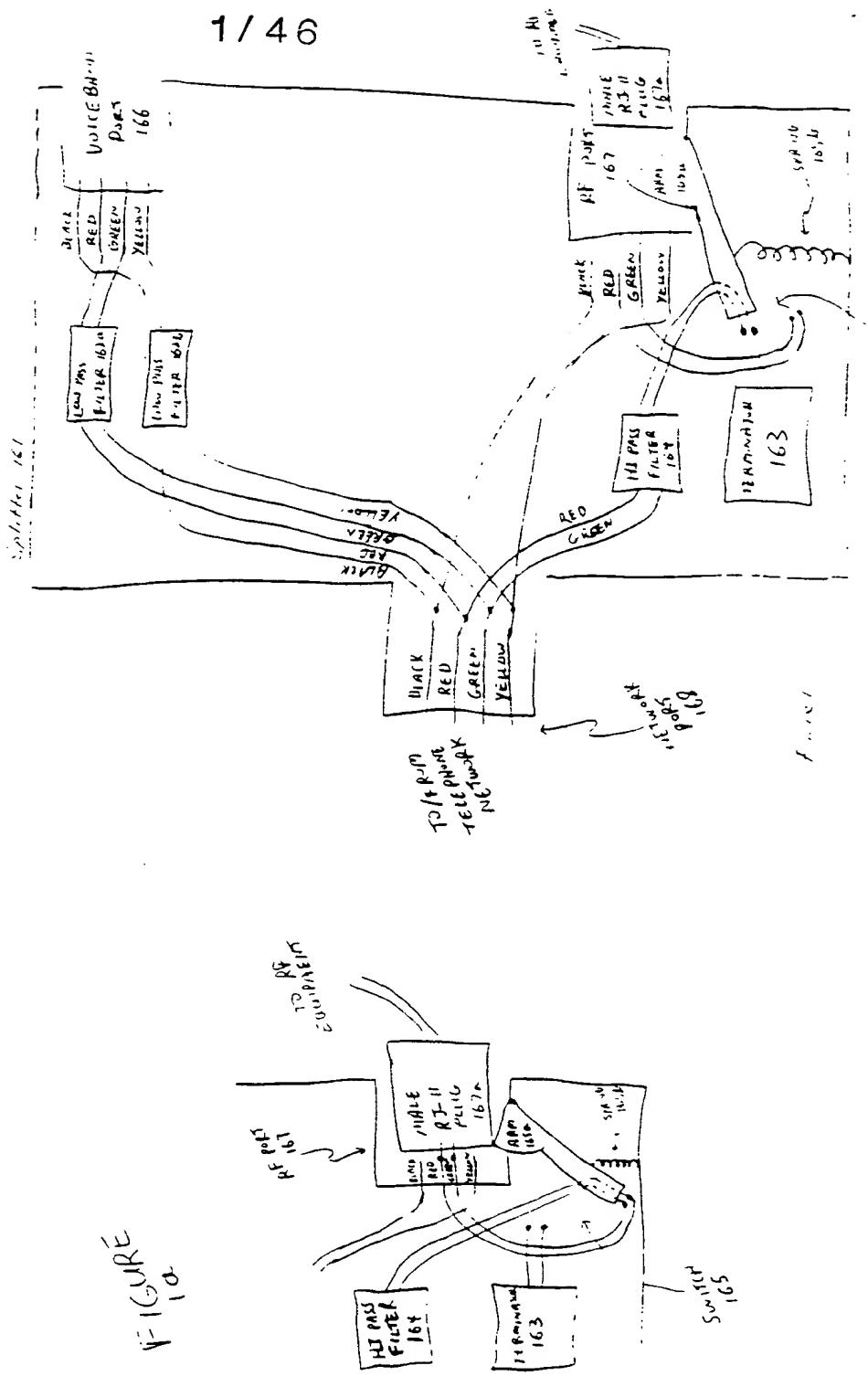
78. The system of claim 1 wherein said source includes a cable having an electrical conductor for carrying said video signal.

15 79. The system of claim 1 wherein said source includes a fibre optic cable for carrying said video signal.

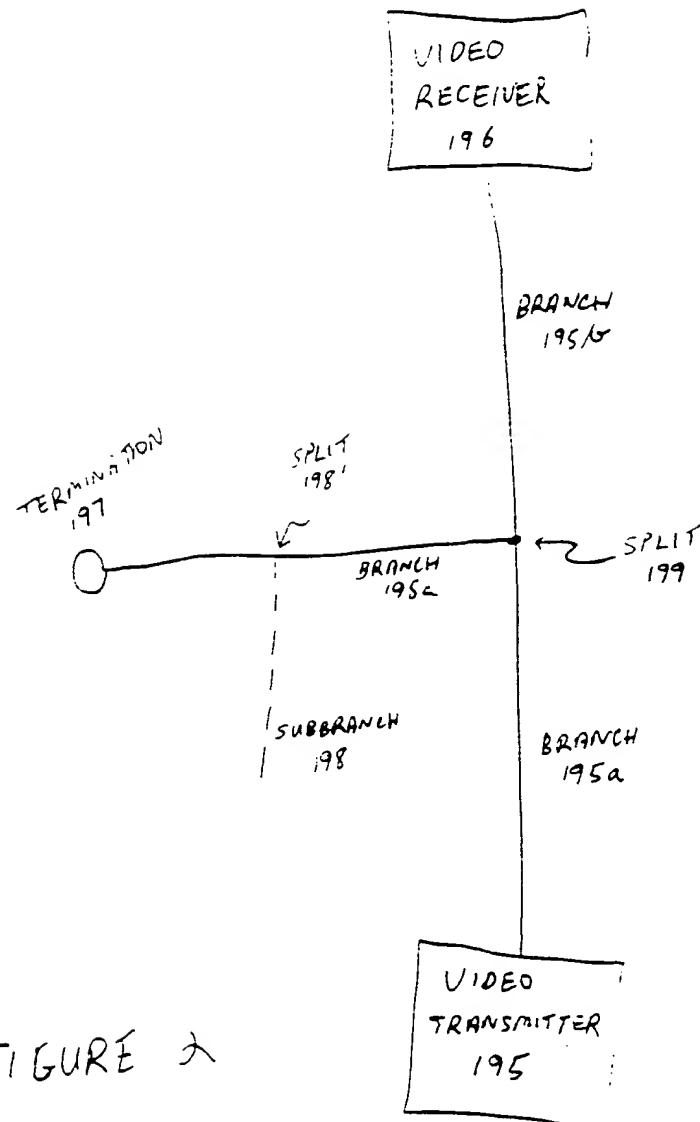
80. A method for video signal communication between a source thereof and a plurality of units that include 20 destinations of said video signal, said method comprising receiving said video signal from said source at an interface coupled to said source and to telephone lines, each of said telephone lines serving at least one of said units and carrying voice signals to and from one or more 25 telephones coupled to said line at said unit, and transmitting said received video signal onto at least one of said telephone lines in a selected frequency range that is different from frequencies at which said

voice signals are carried on said one telephone line to cause said video signal to be coupled to a receiver connected to said telephone line at the unit served by said line, said receiver being adapted to recover said video 5 signal from said telephone line and apply said recovered video signal to one or more of said destinations at said unit.

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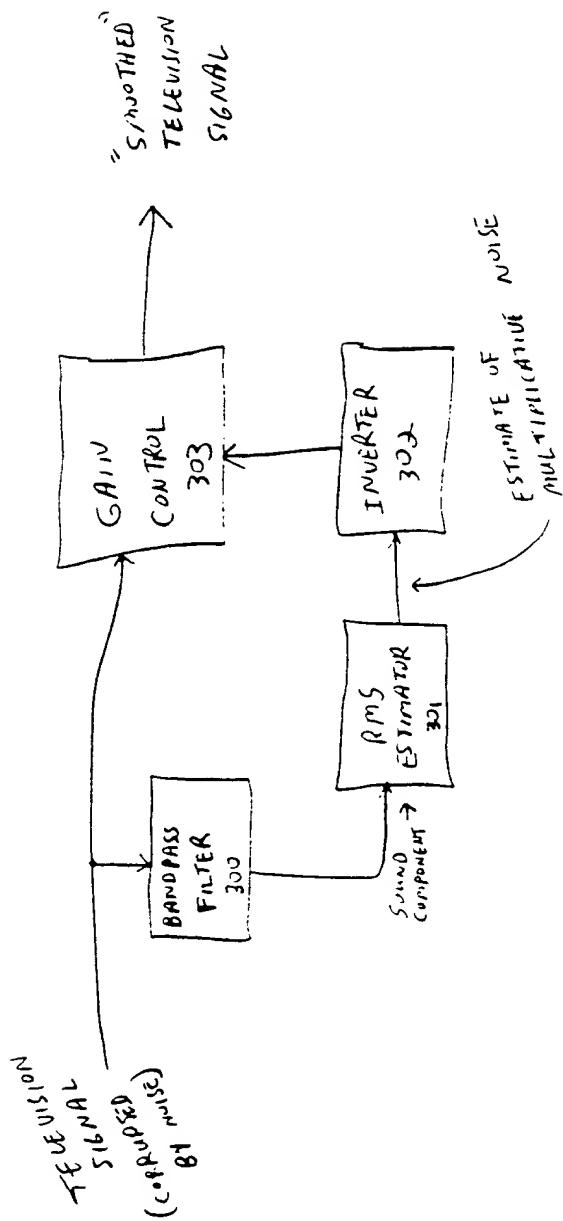


FIGURE 3

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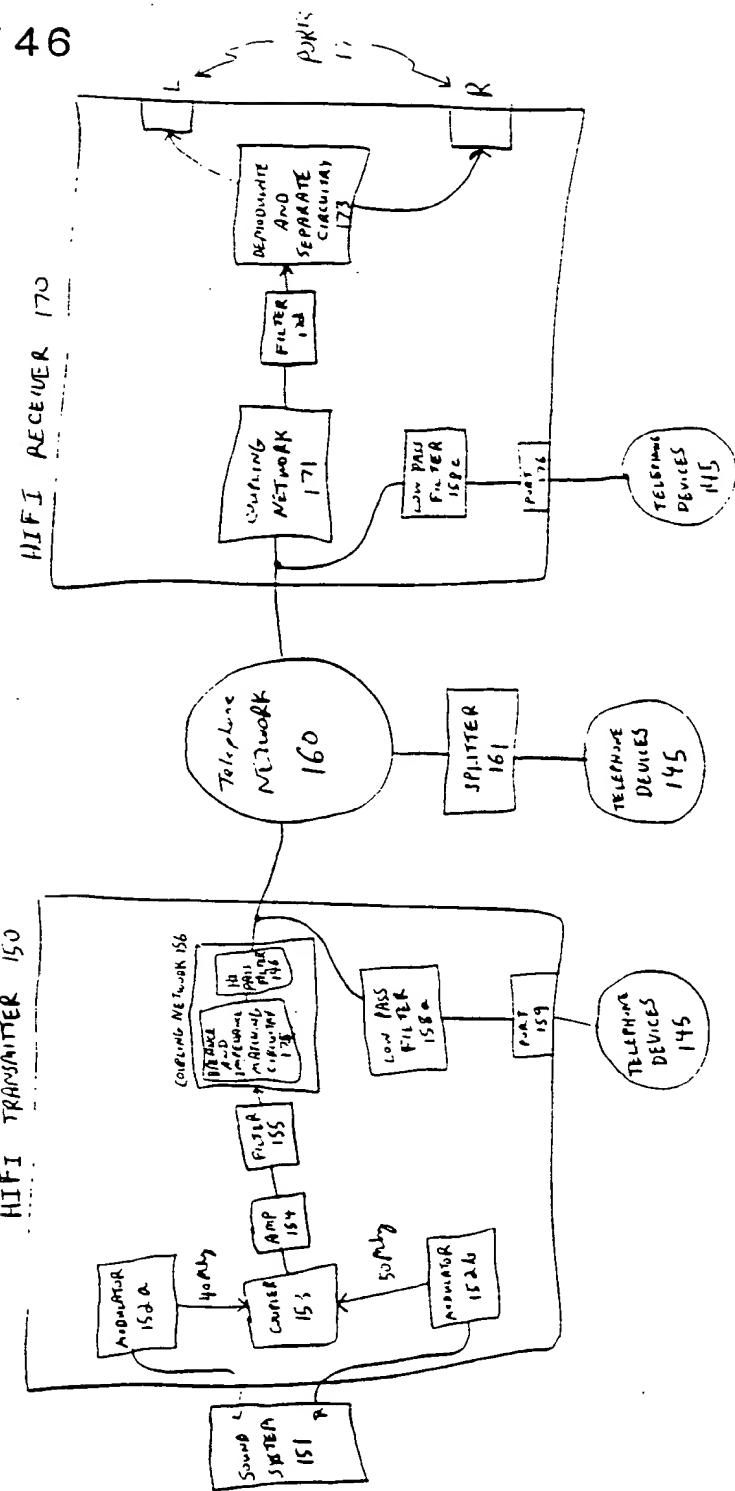


FIGURE 1a

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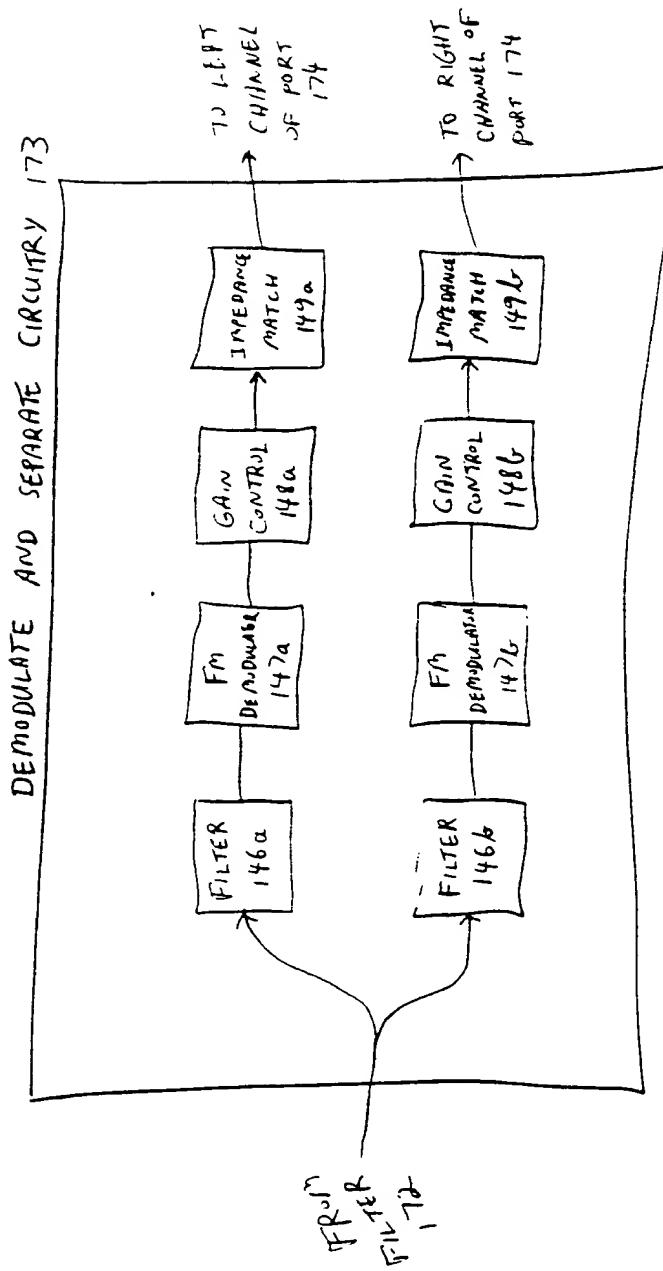


FIGURE 4b

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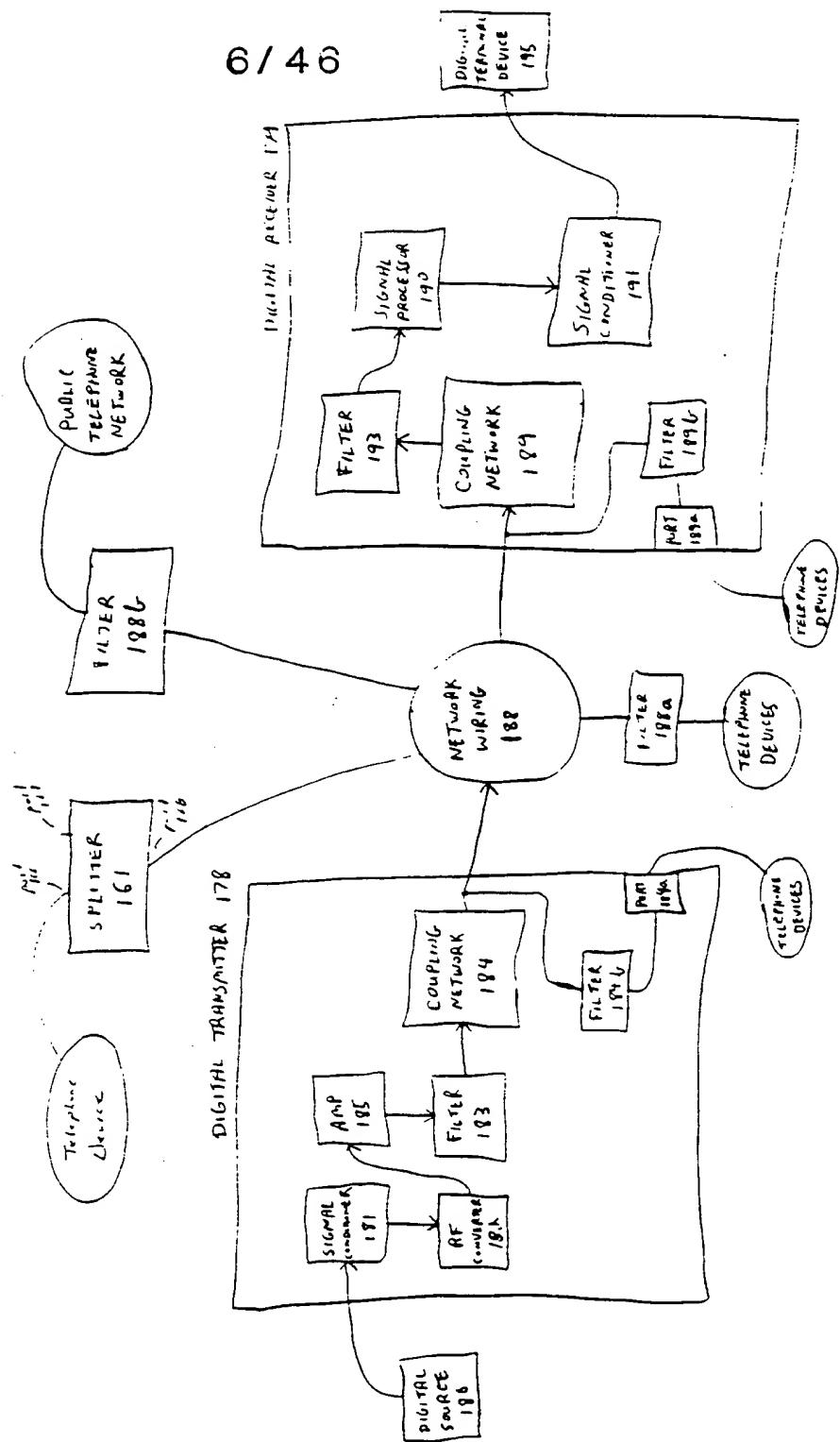


FIGURE 5

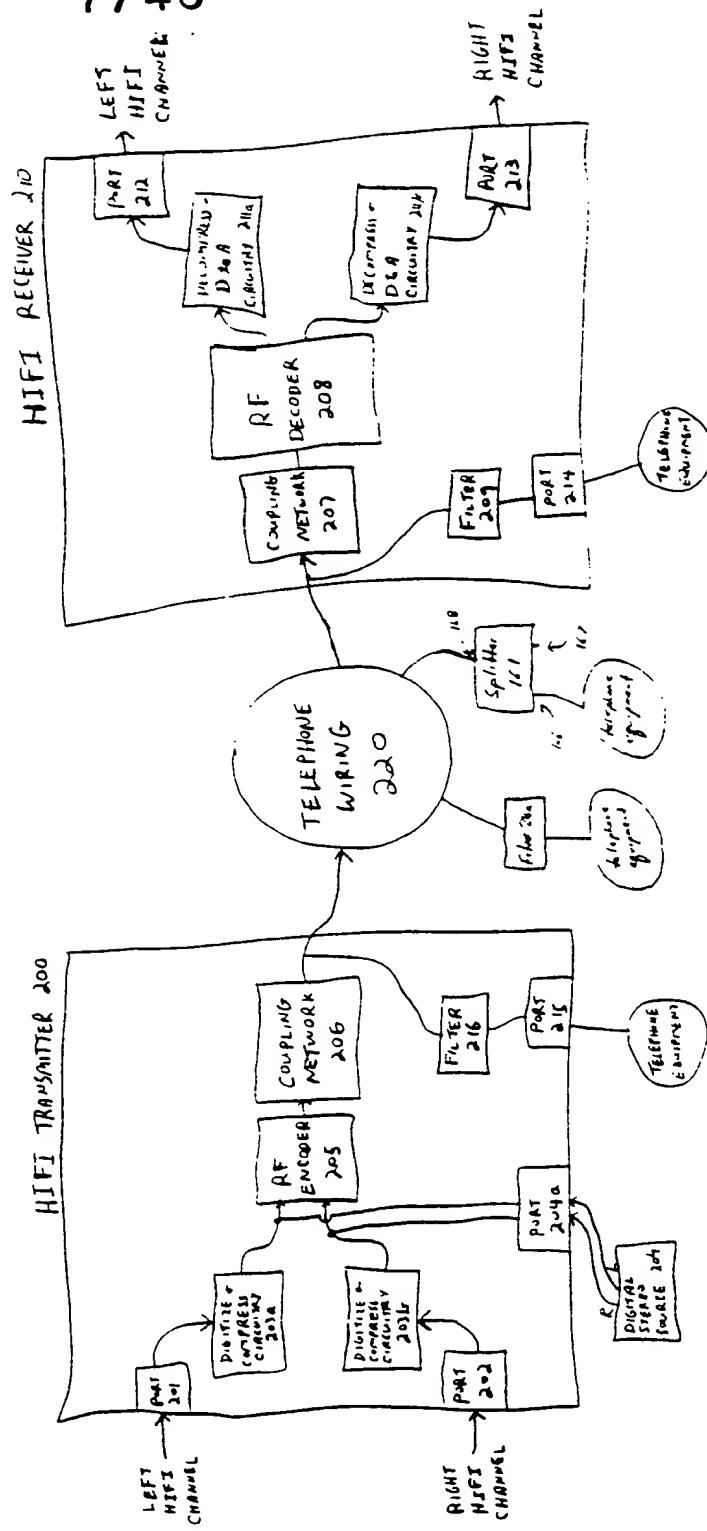


FIGURE 6

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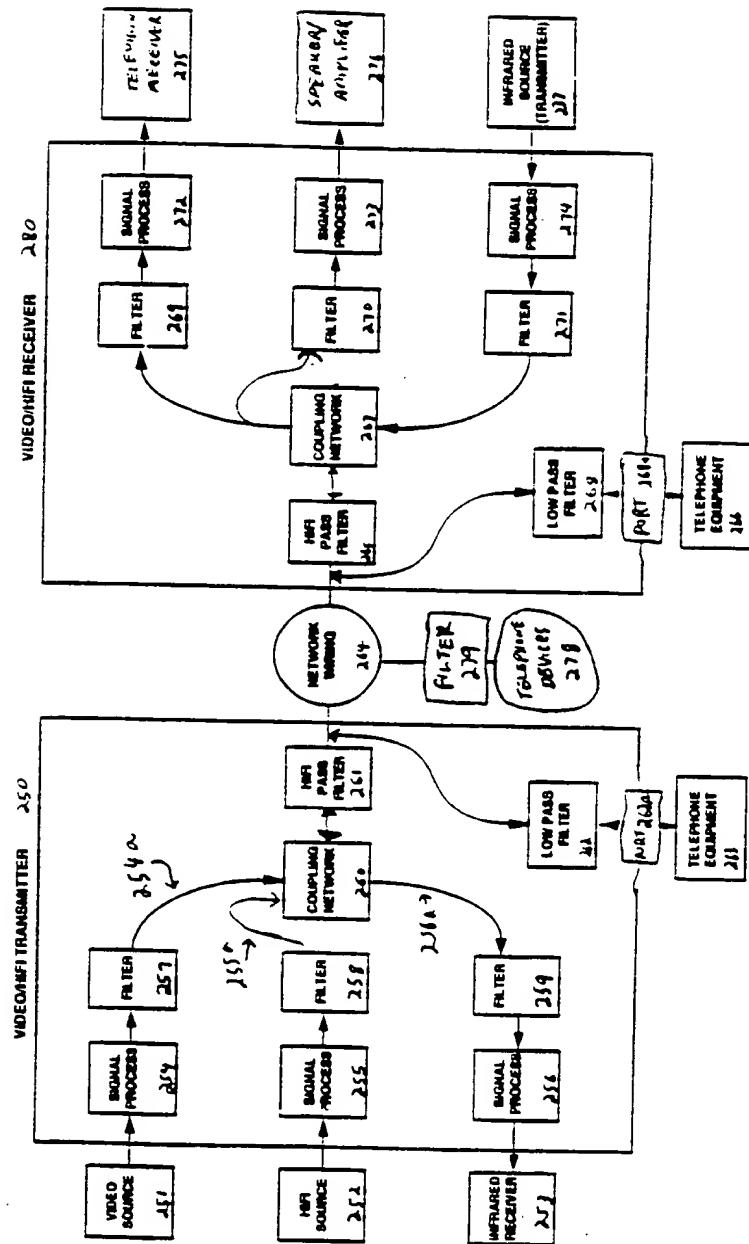


FIGURE 7

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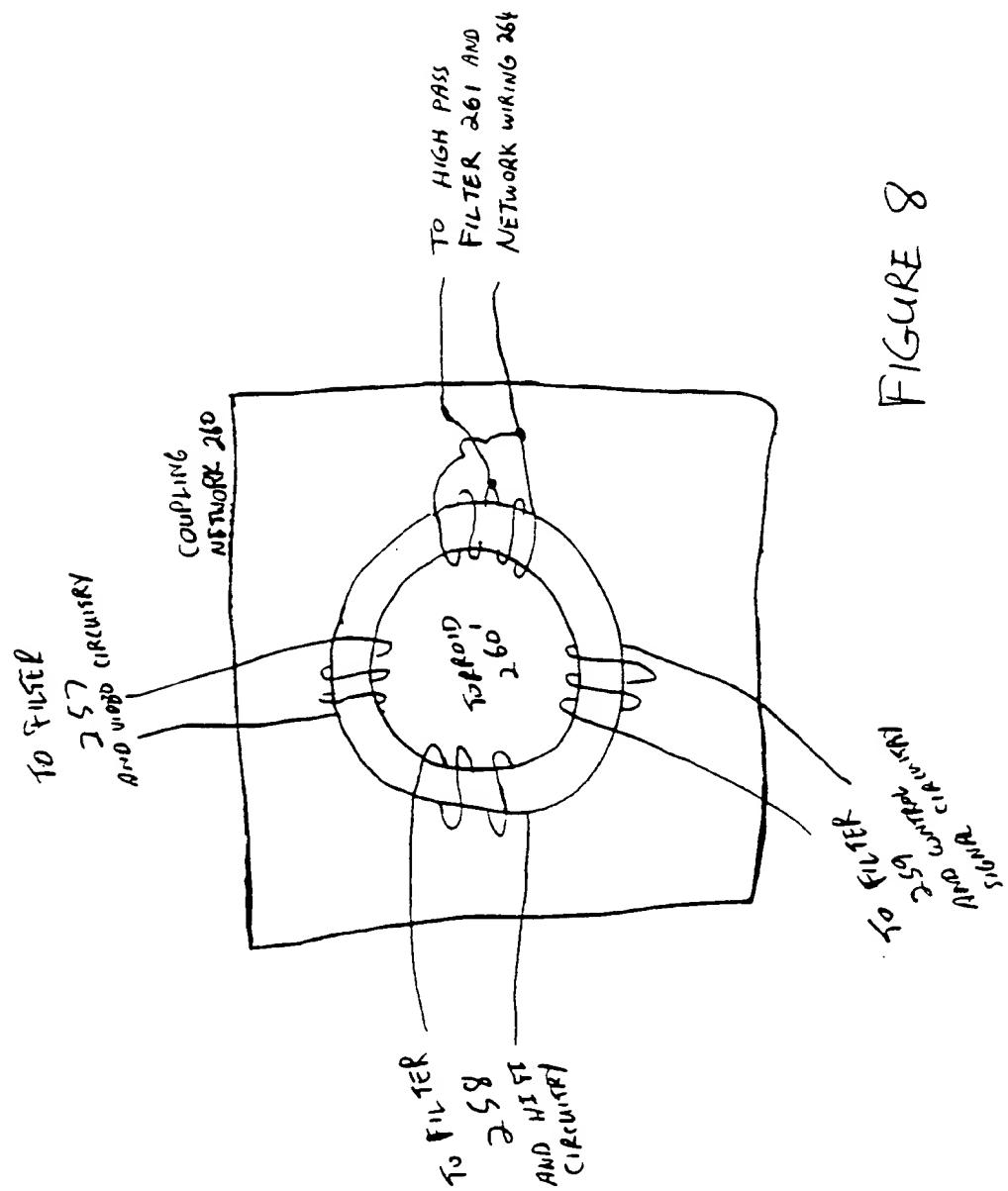
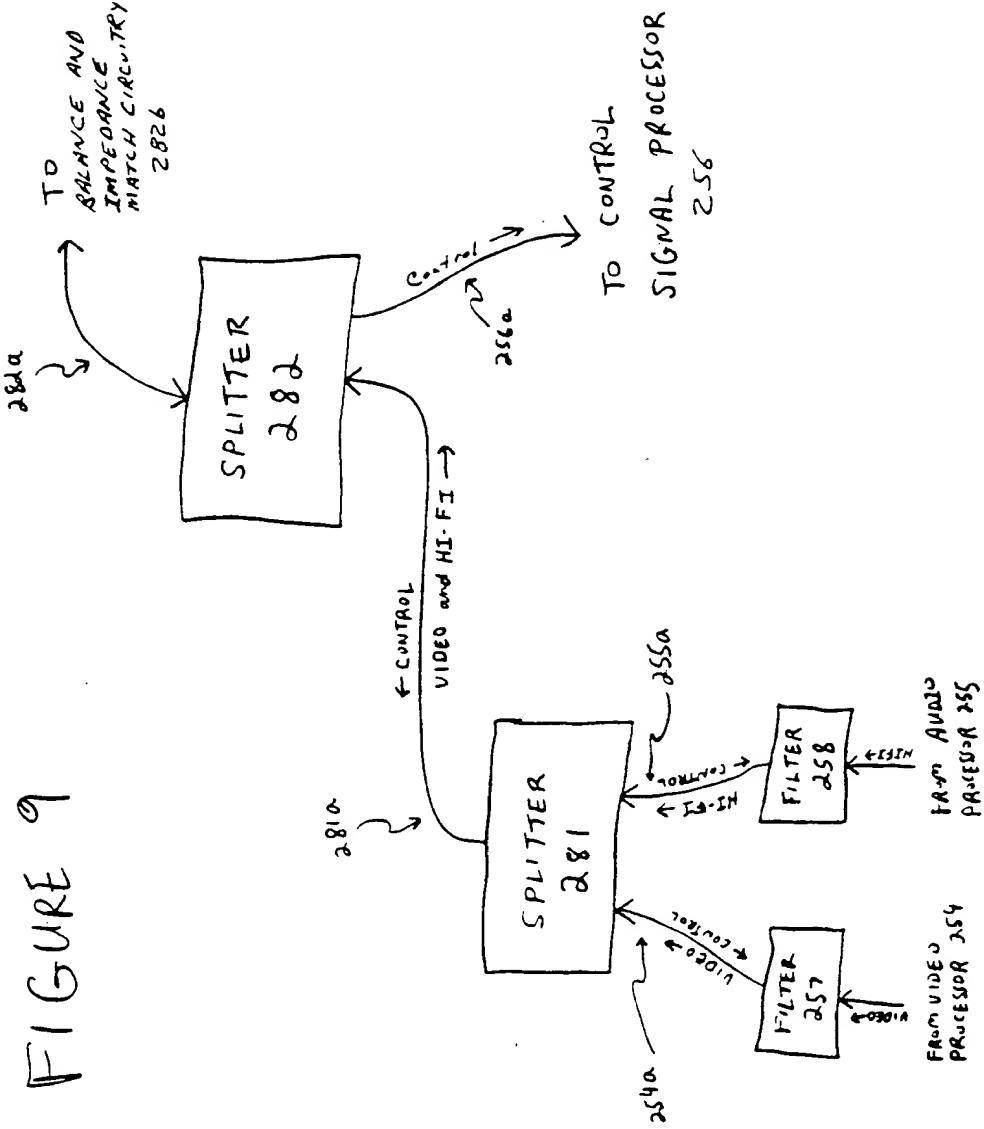
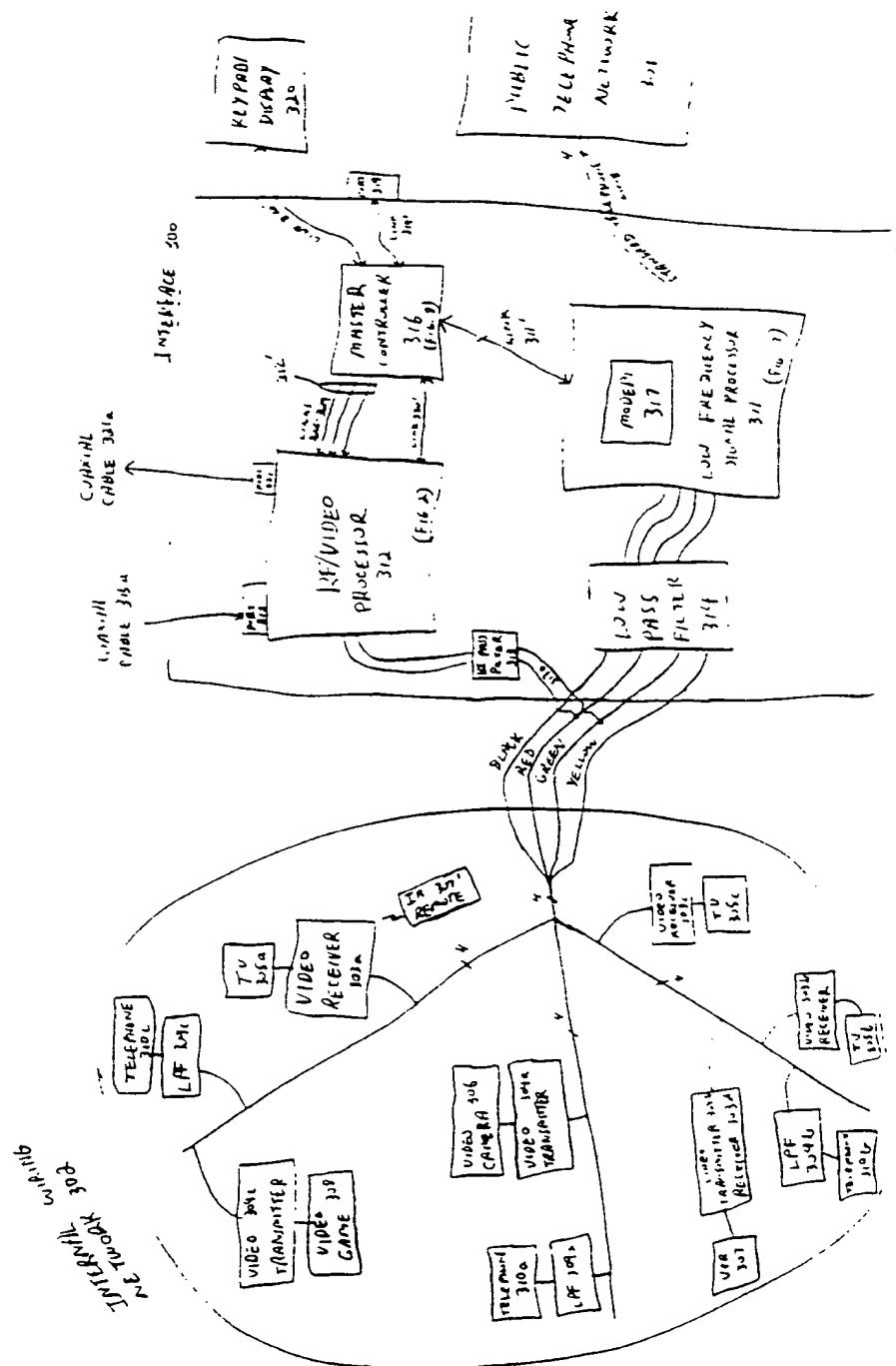


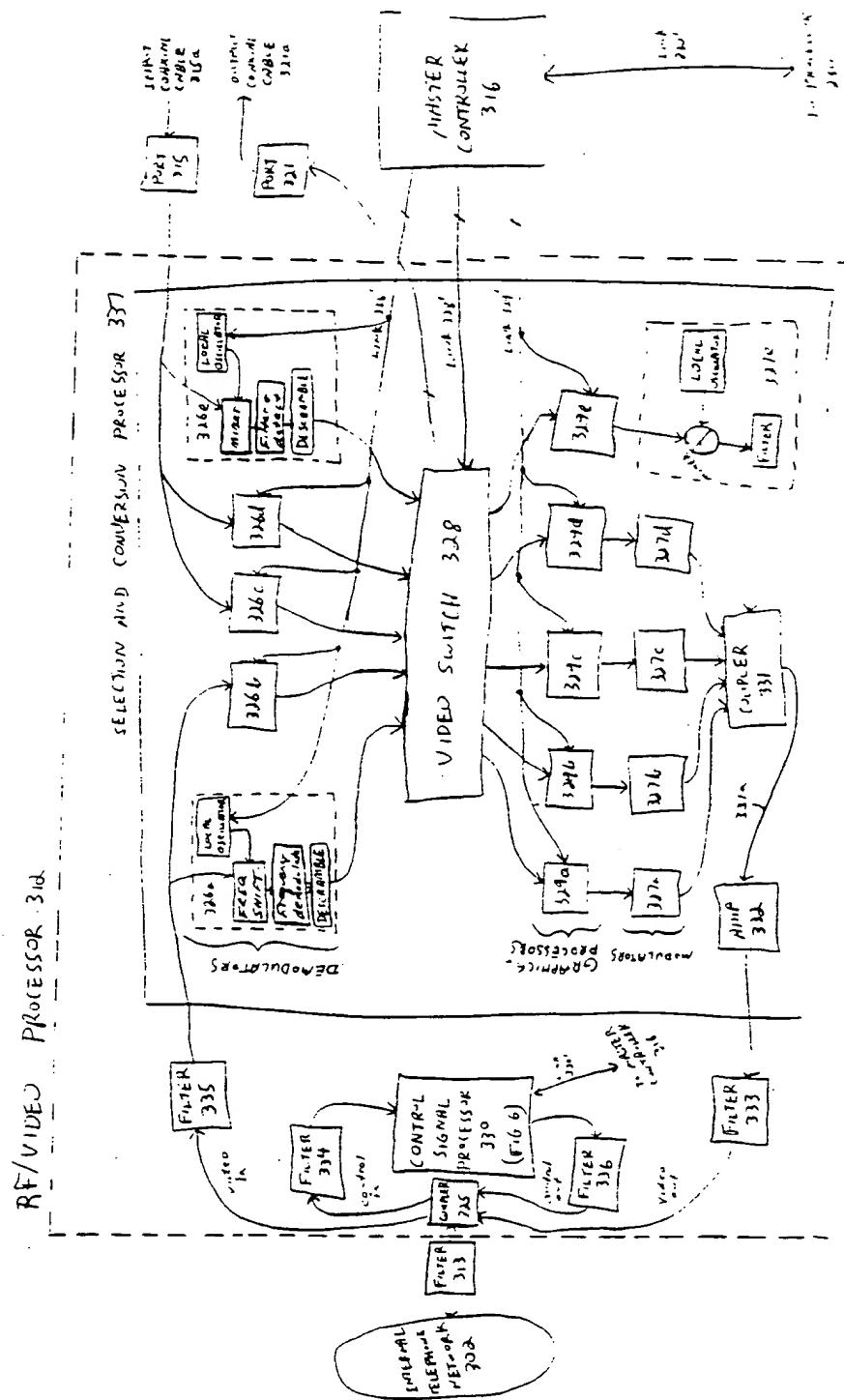
FIGURE 8

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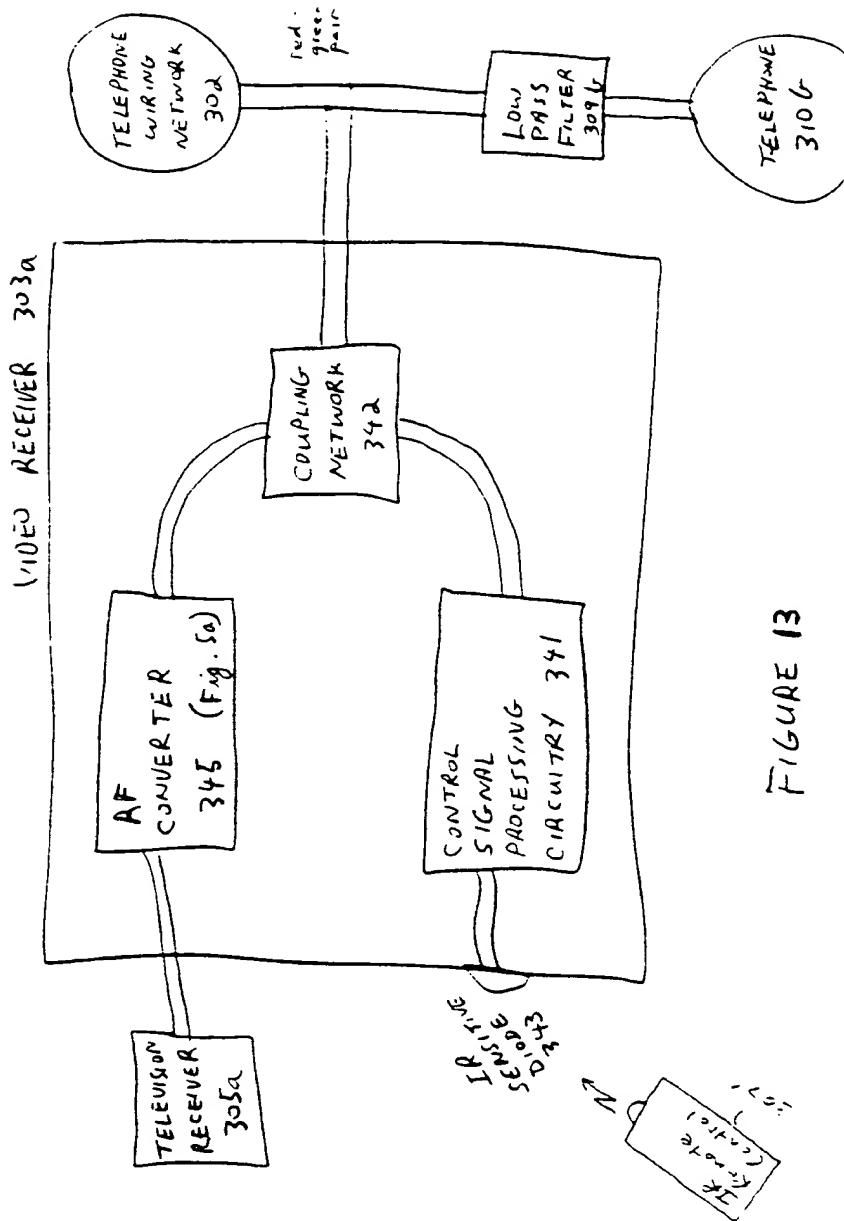


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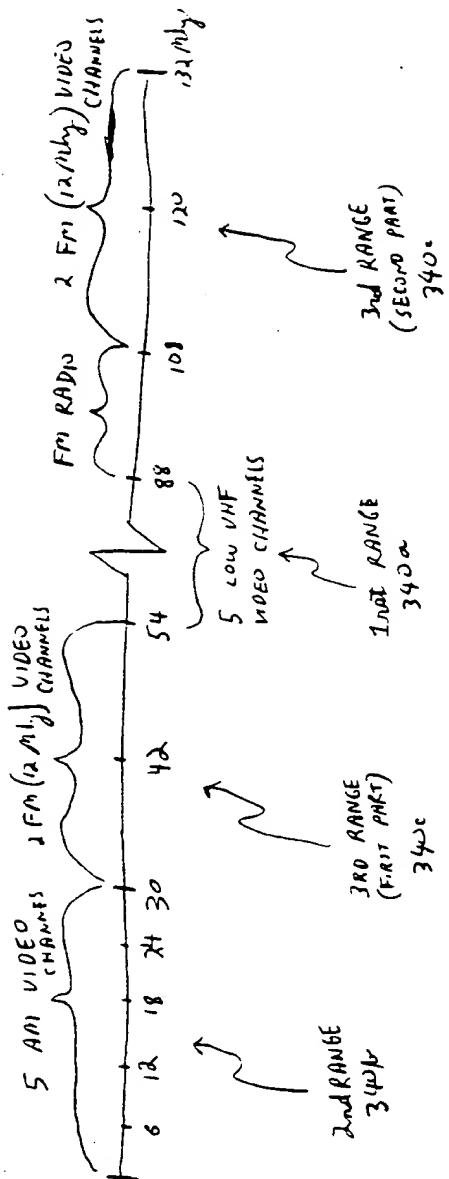


FIGURE 14a

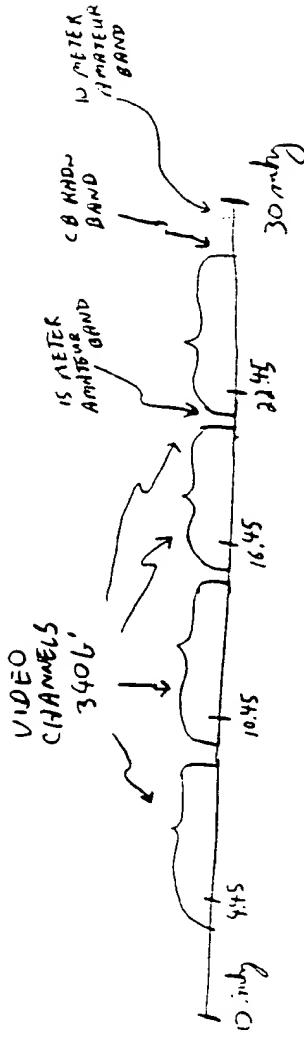


FIGURE 14b

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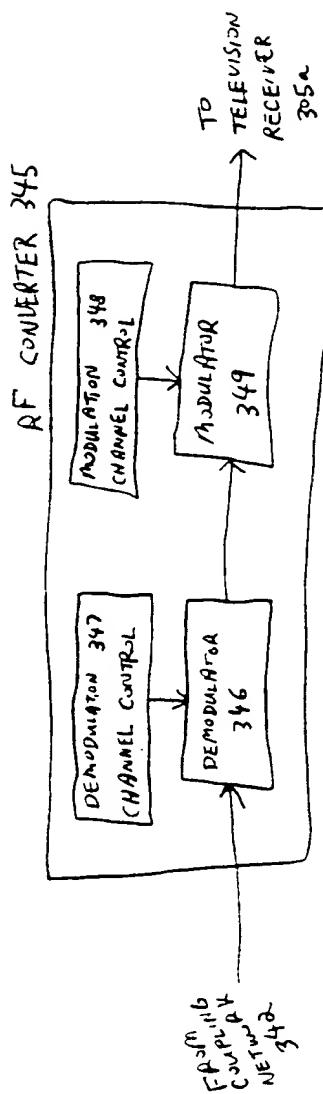
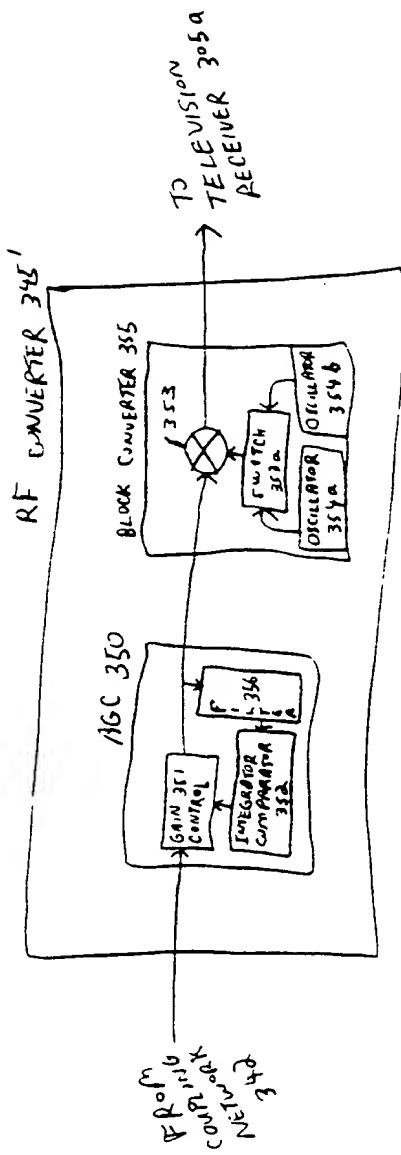


FIG. 15a



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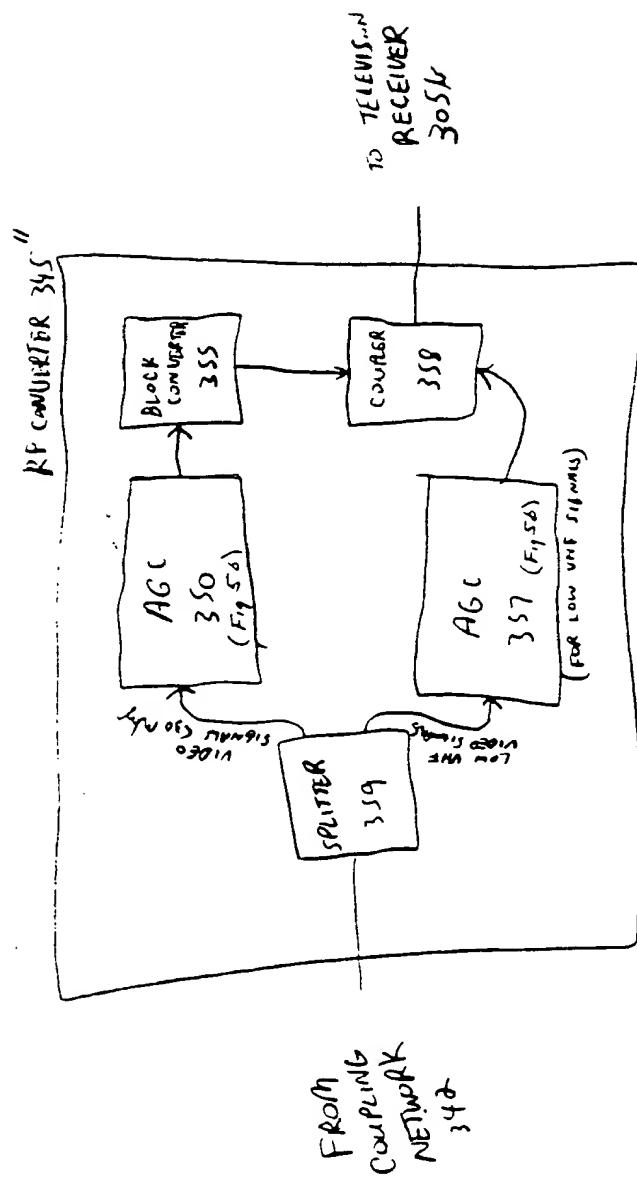


FIG. 15C

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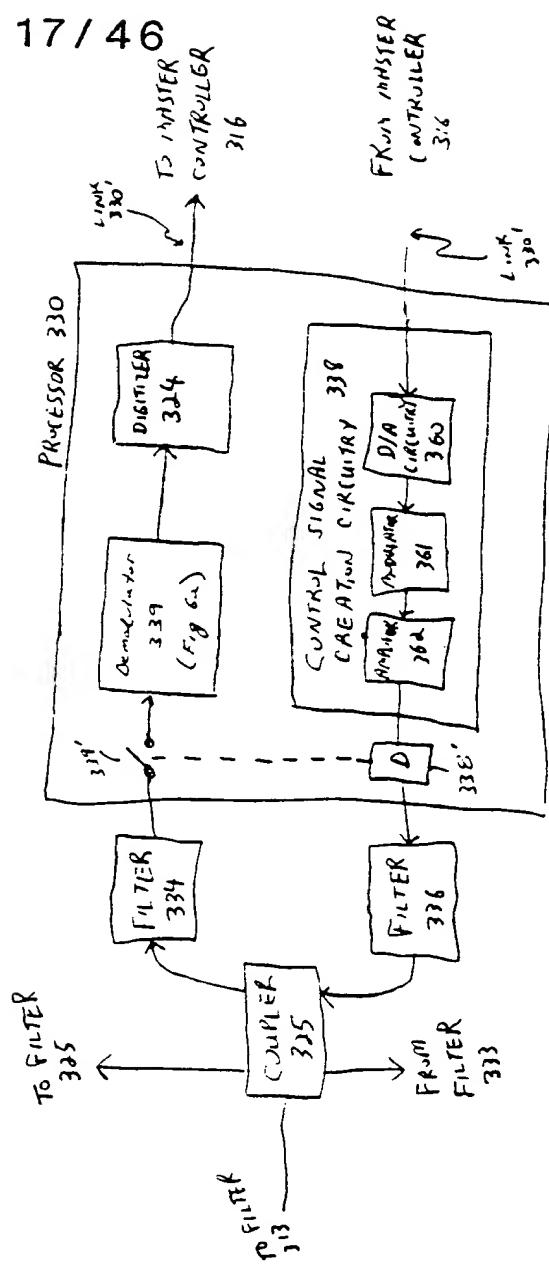


FIGURE 16

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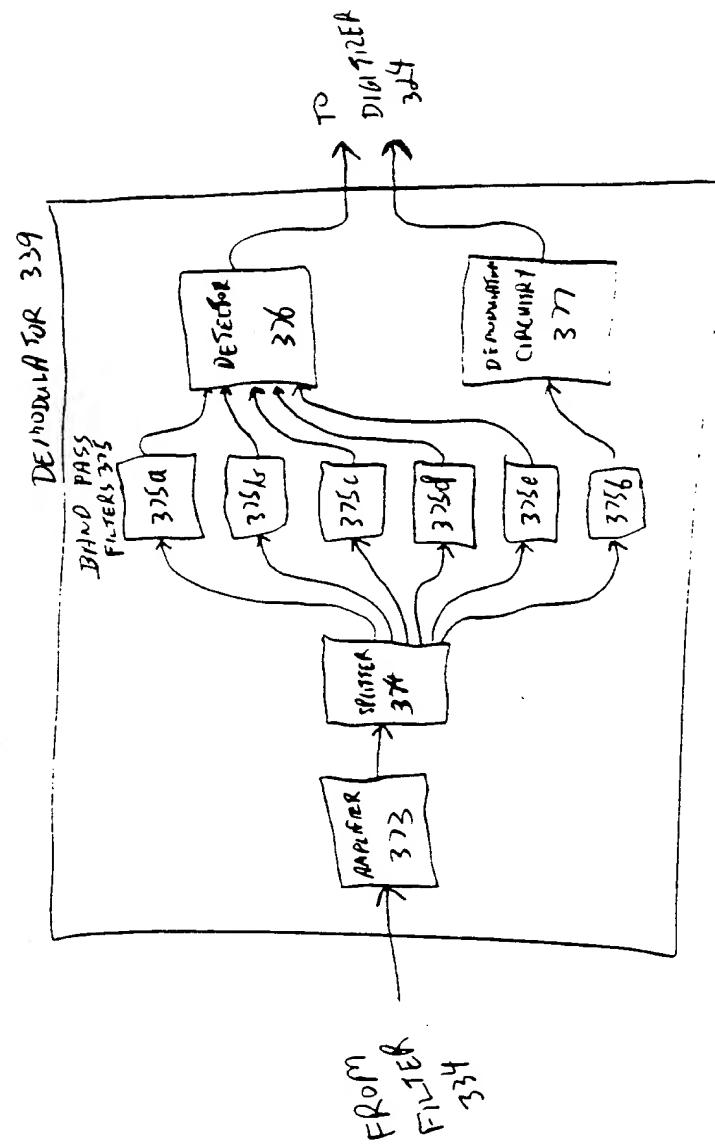


FIGURE 16a

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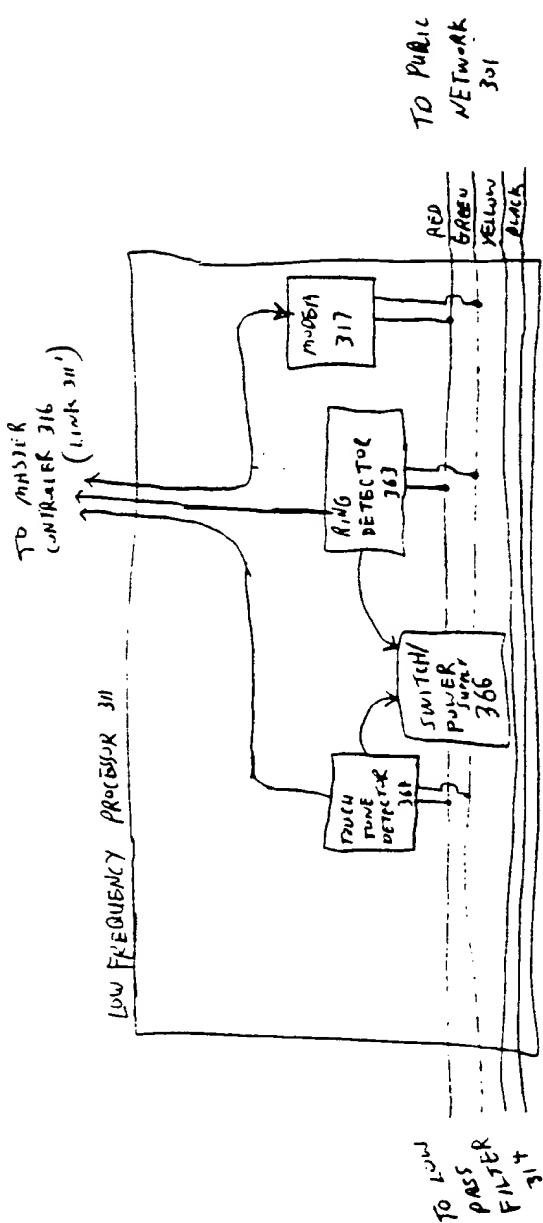
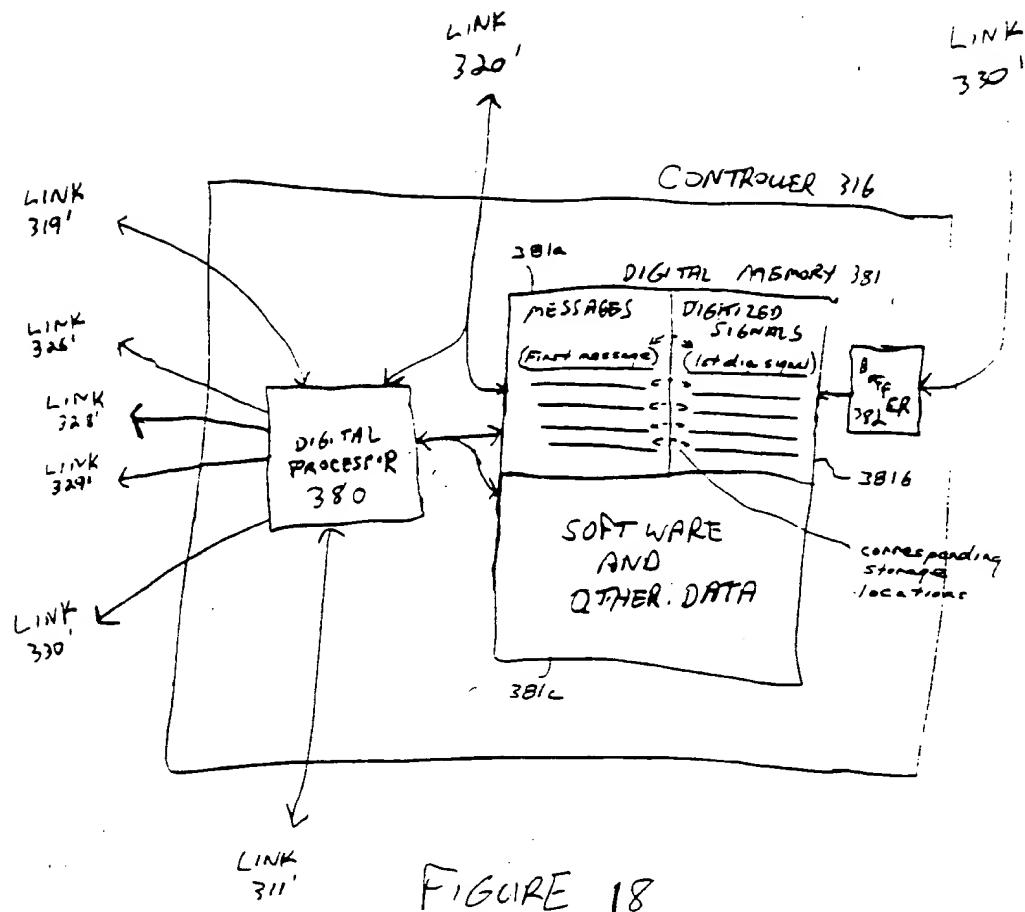


FIGURE 17

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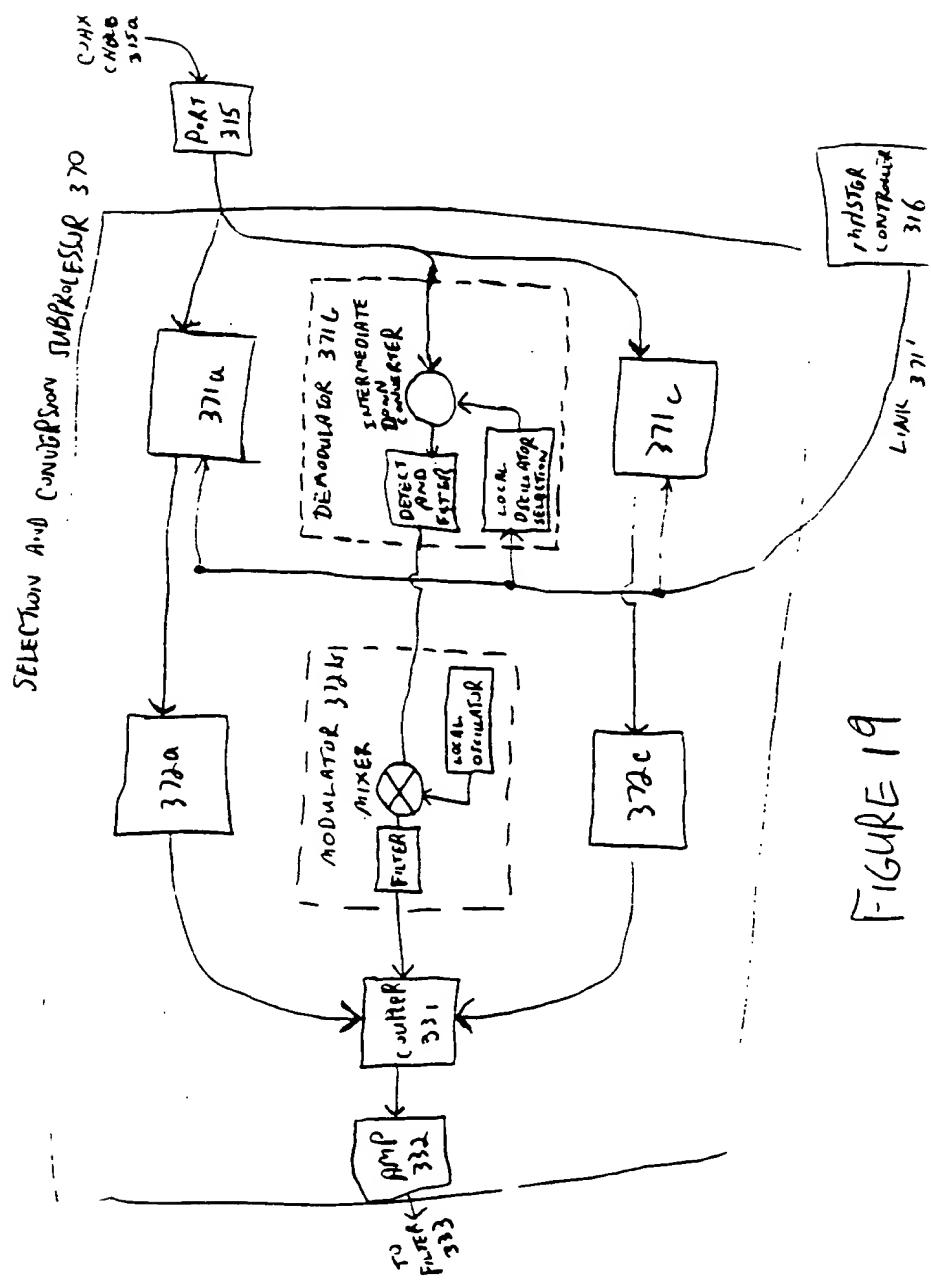
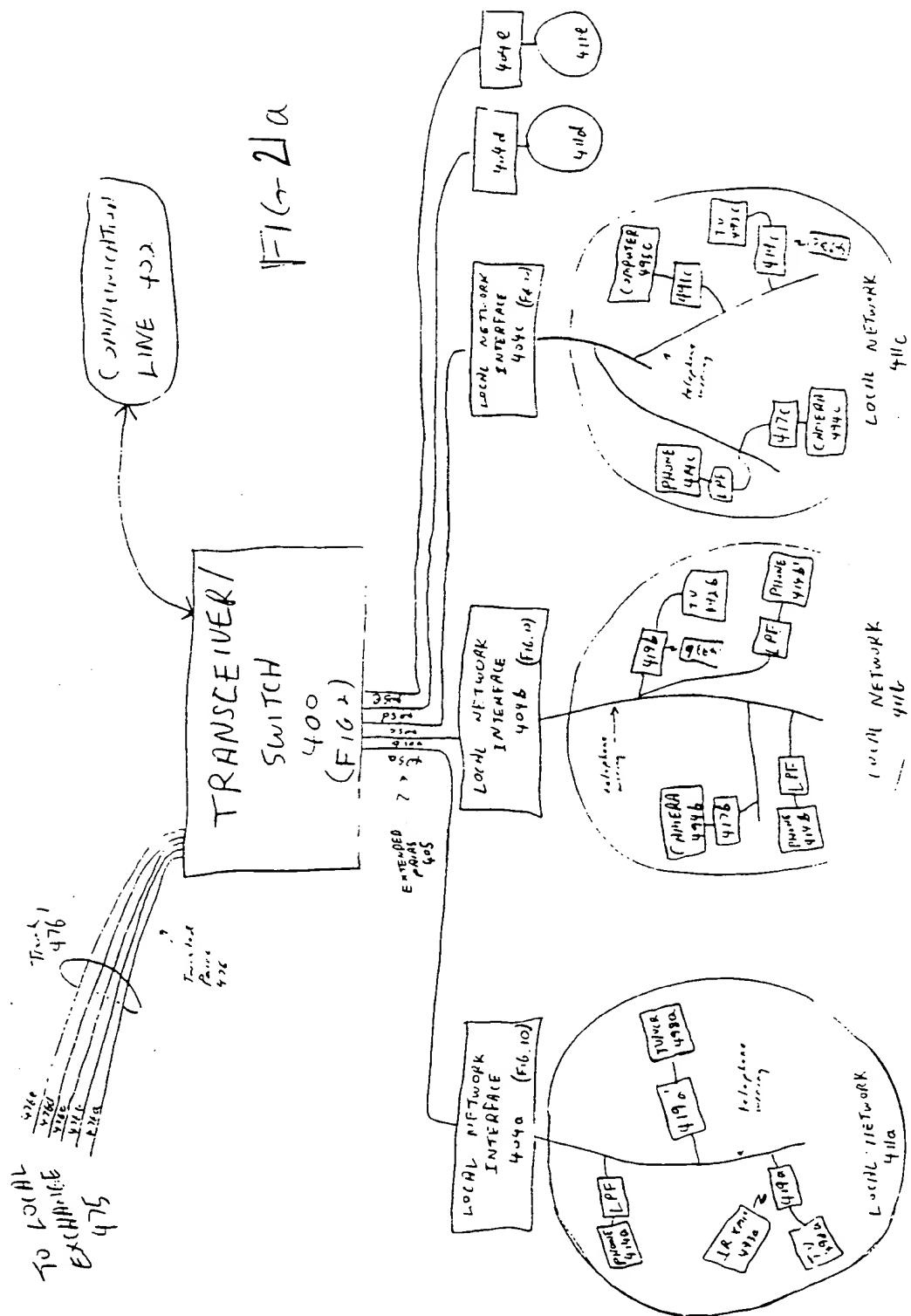
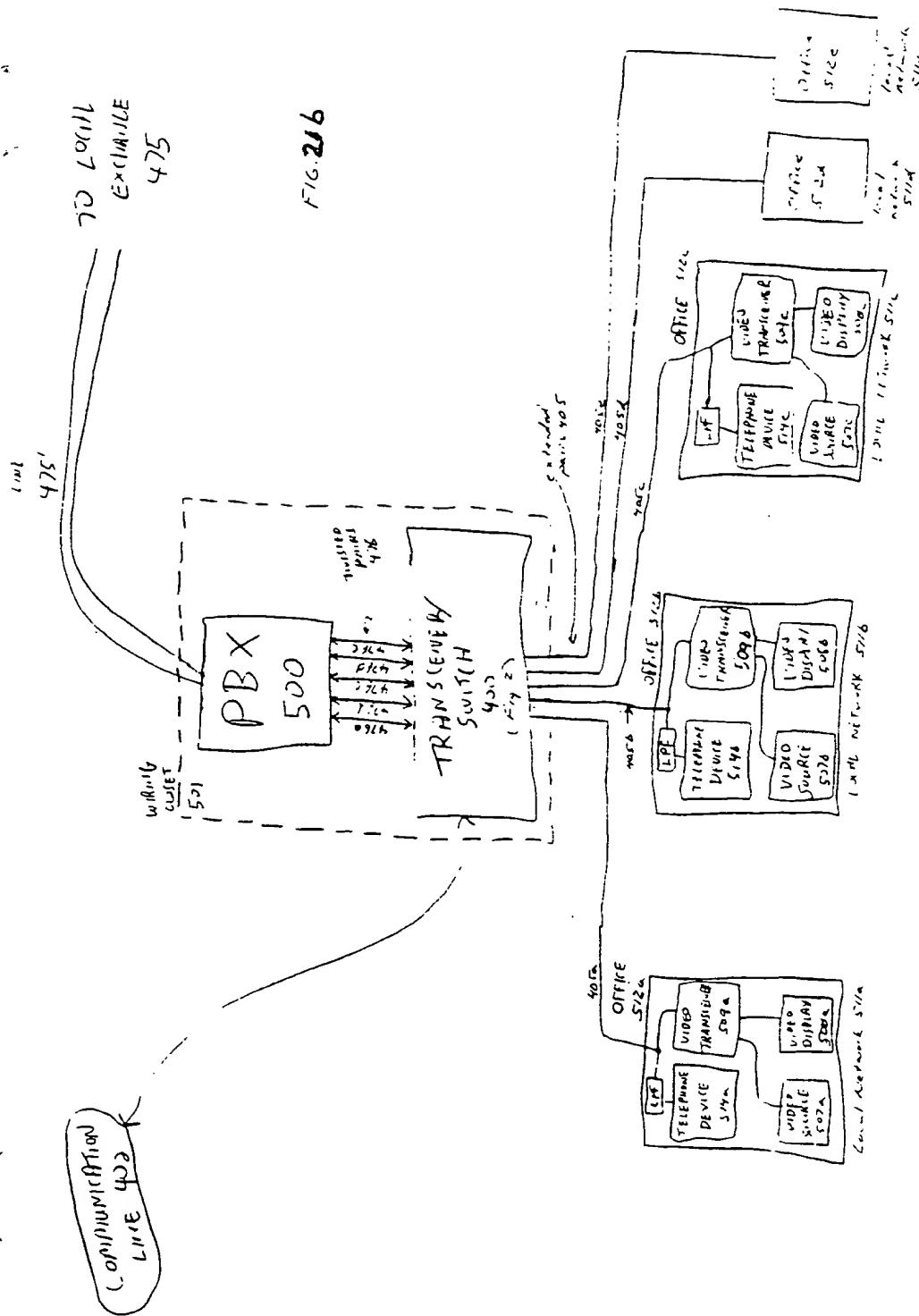


FIGURE 19

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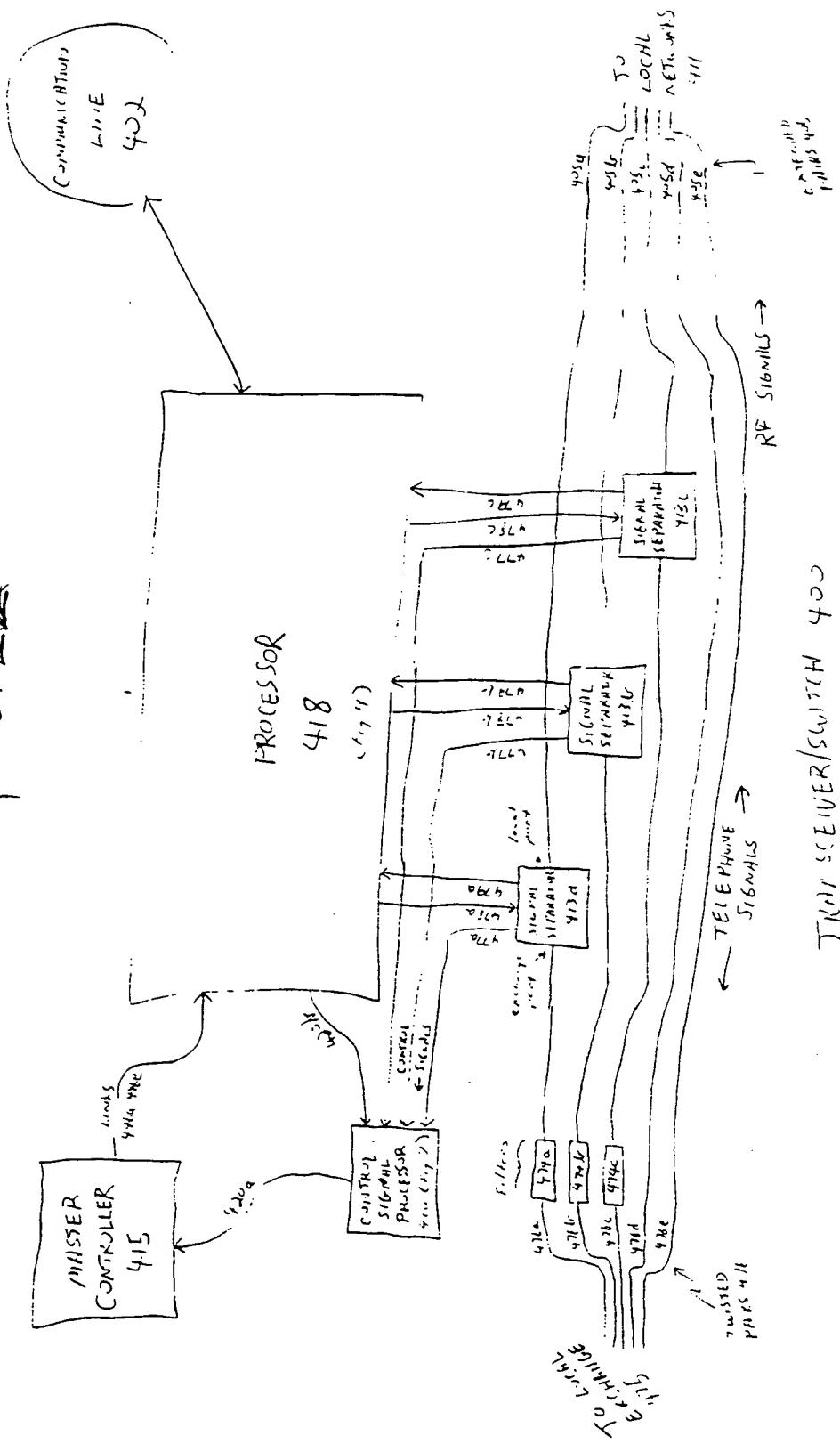


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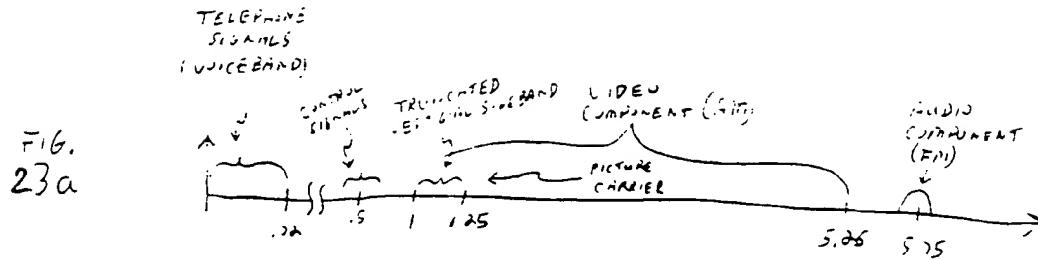


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FIG. 22

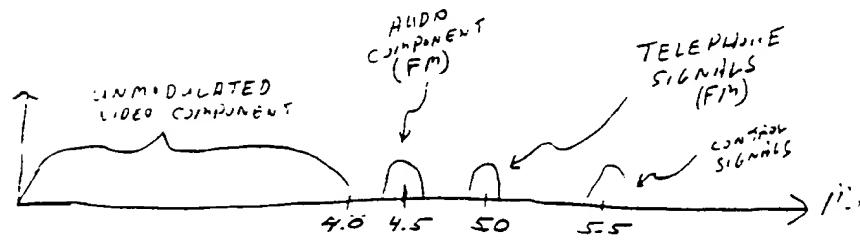


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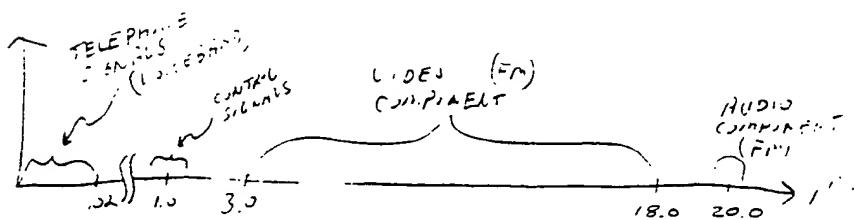
SPECTRUM OF AN AMPLITUDE MODULATED NTSC SIGNAL NEAR VOICEBAND

FIG. 23b



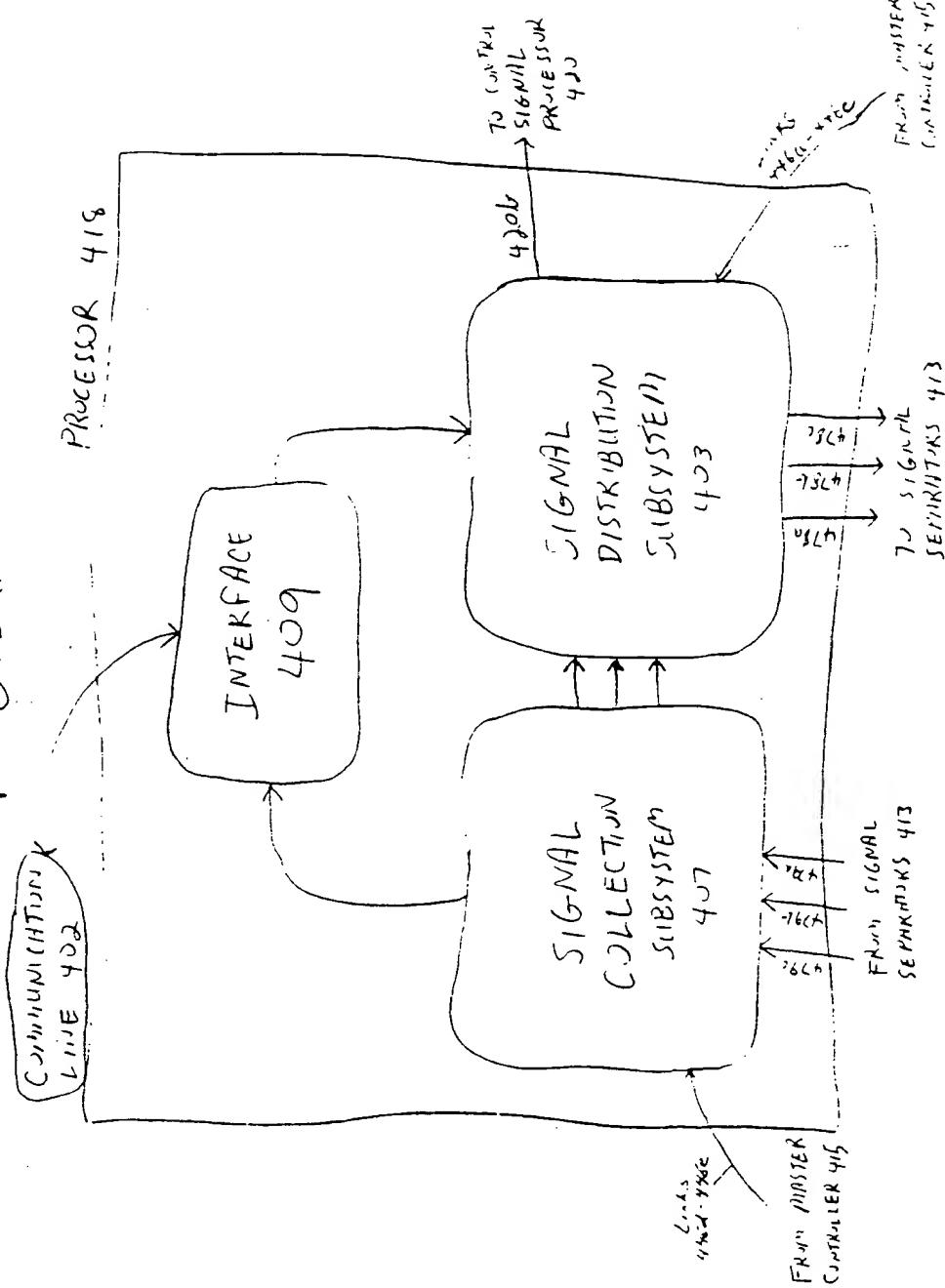
SPECTRUM OF AN NTSC SIGNAL TRANSMITTING AT BASEBAND

FIG. 23c



SPECTRUM OF AN FM NTSC SIGNAL NEAR VOICEBAND

F 16.24



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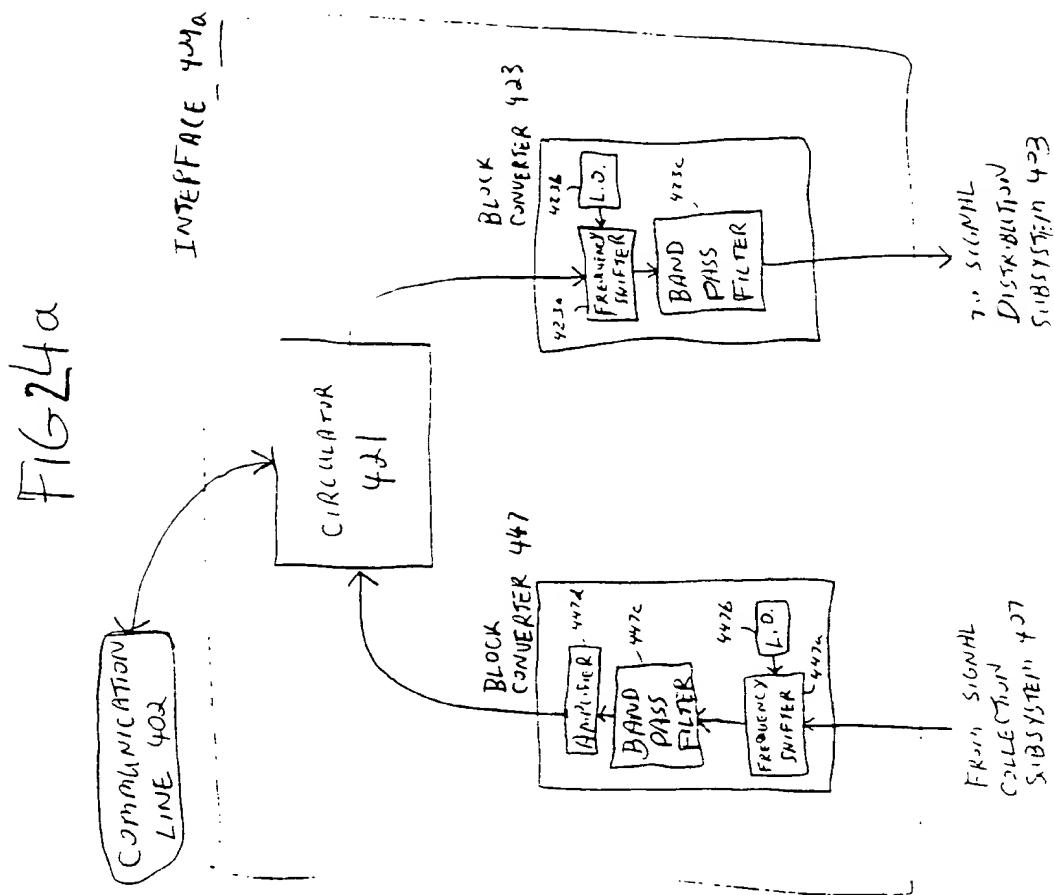
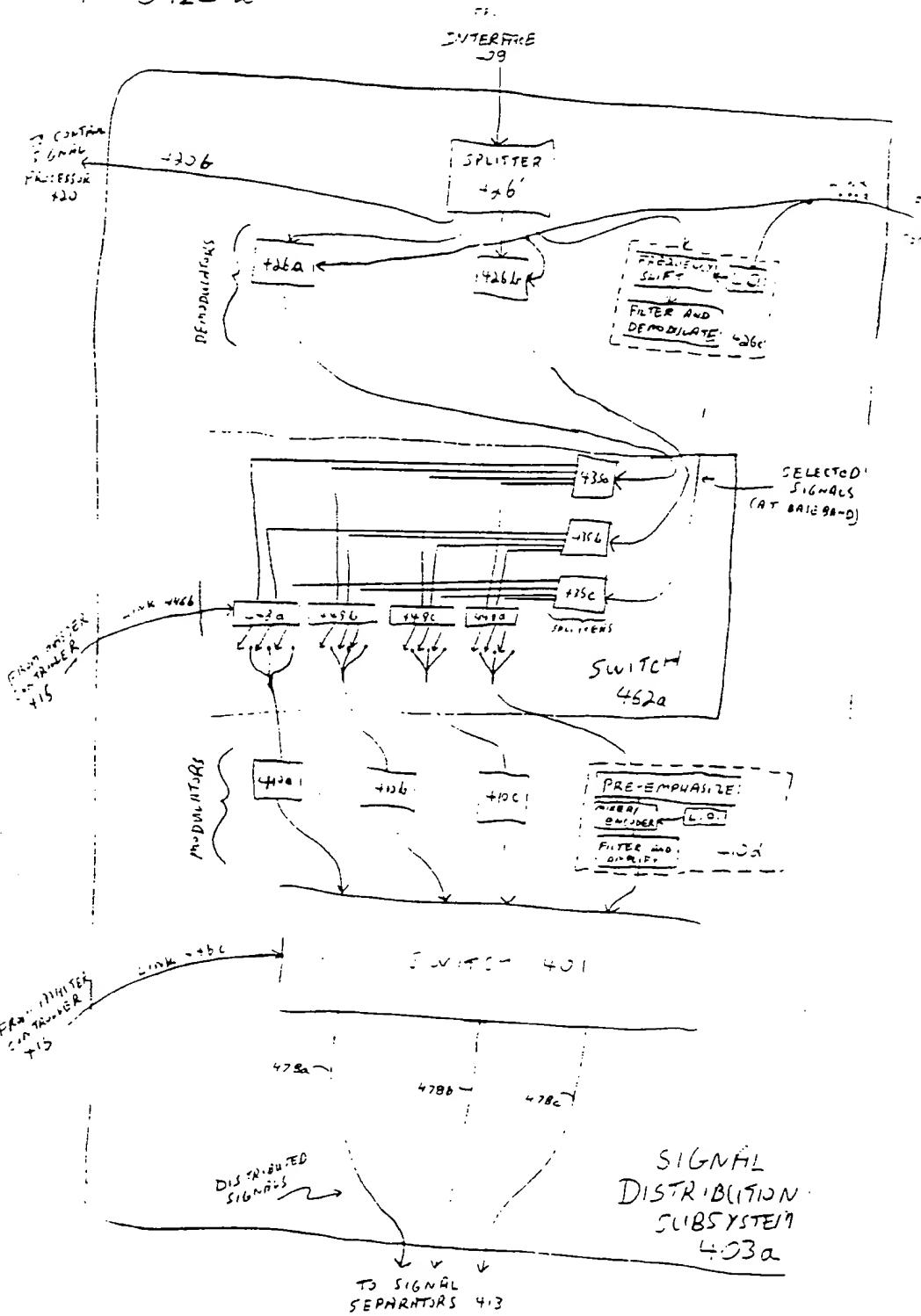
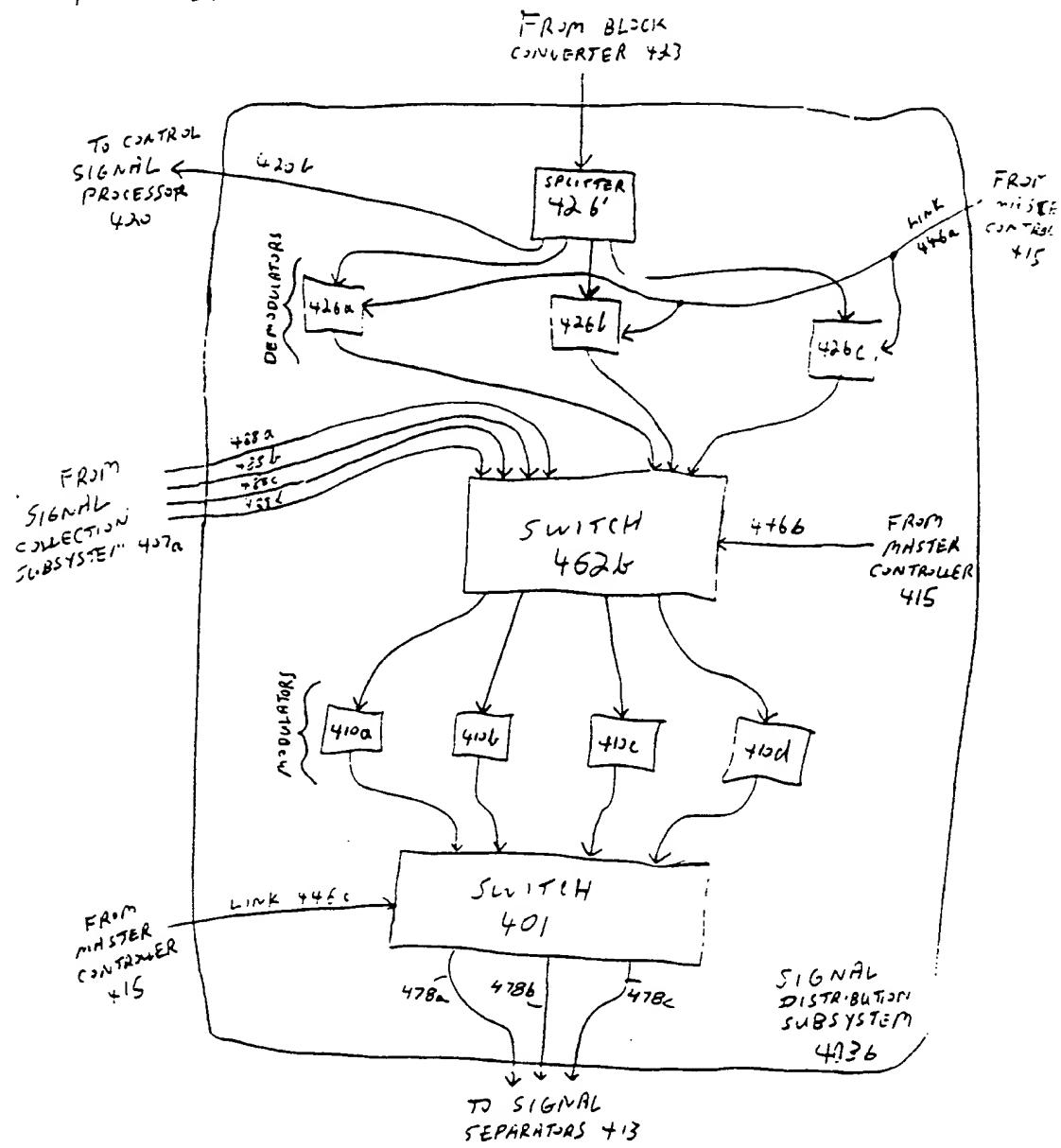


FIG. 25a



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FIG. 25b



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FIG. 25C

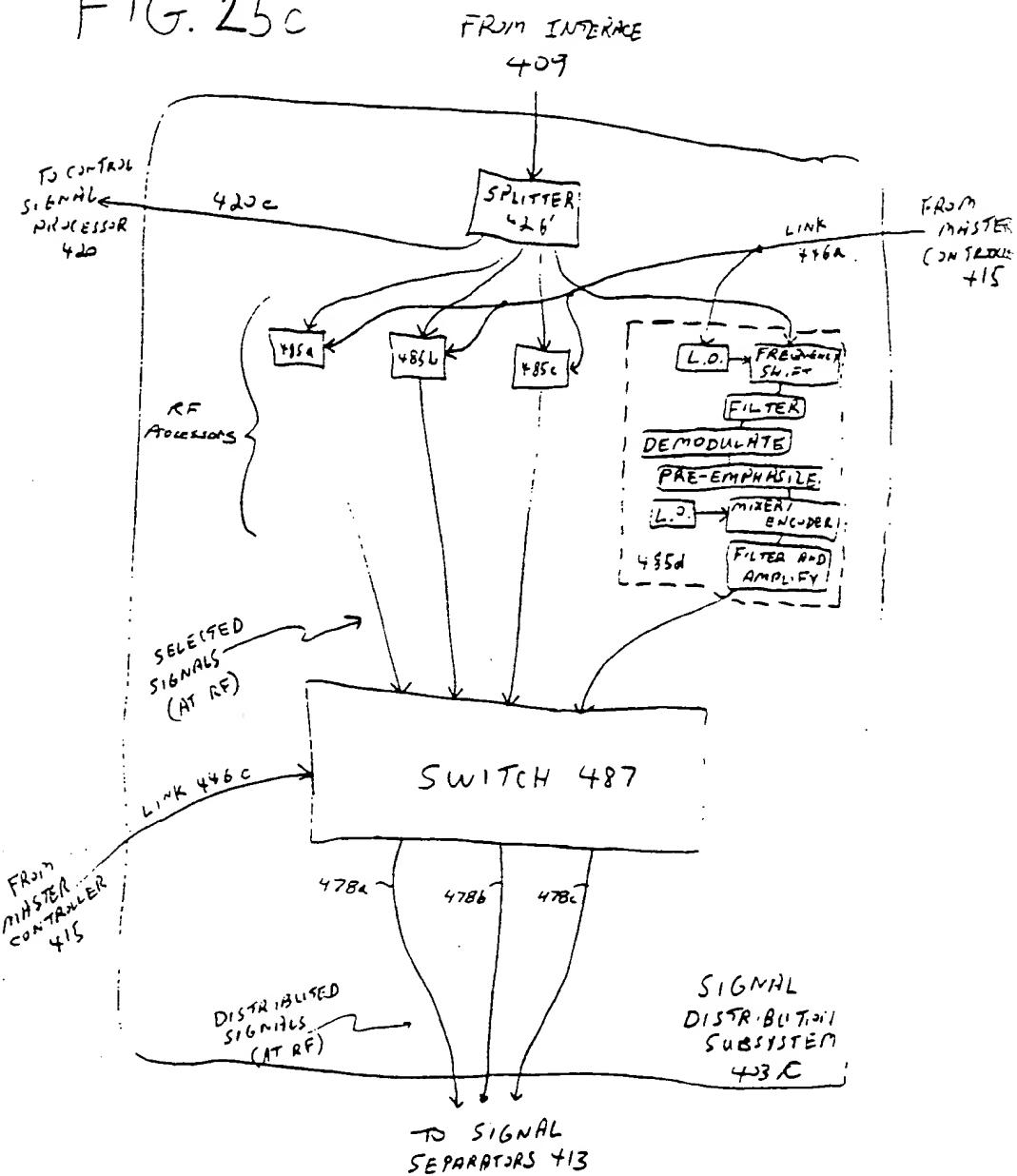


FIG. 26a

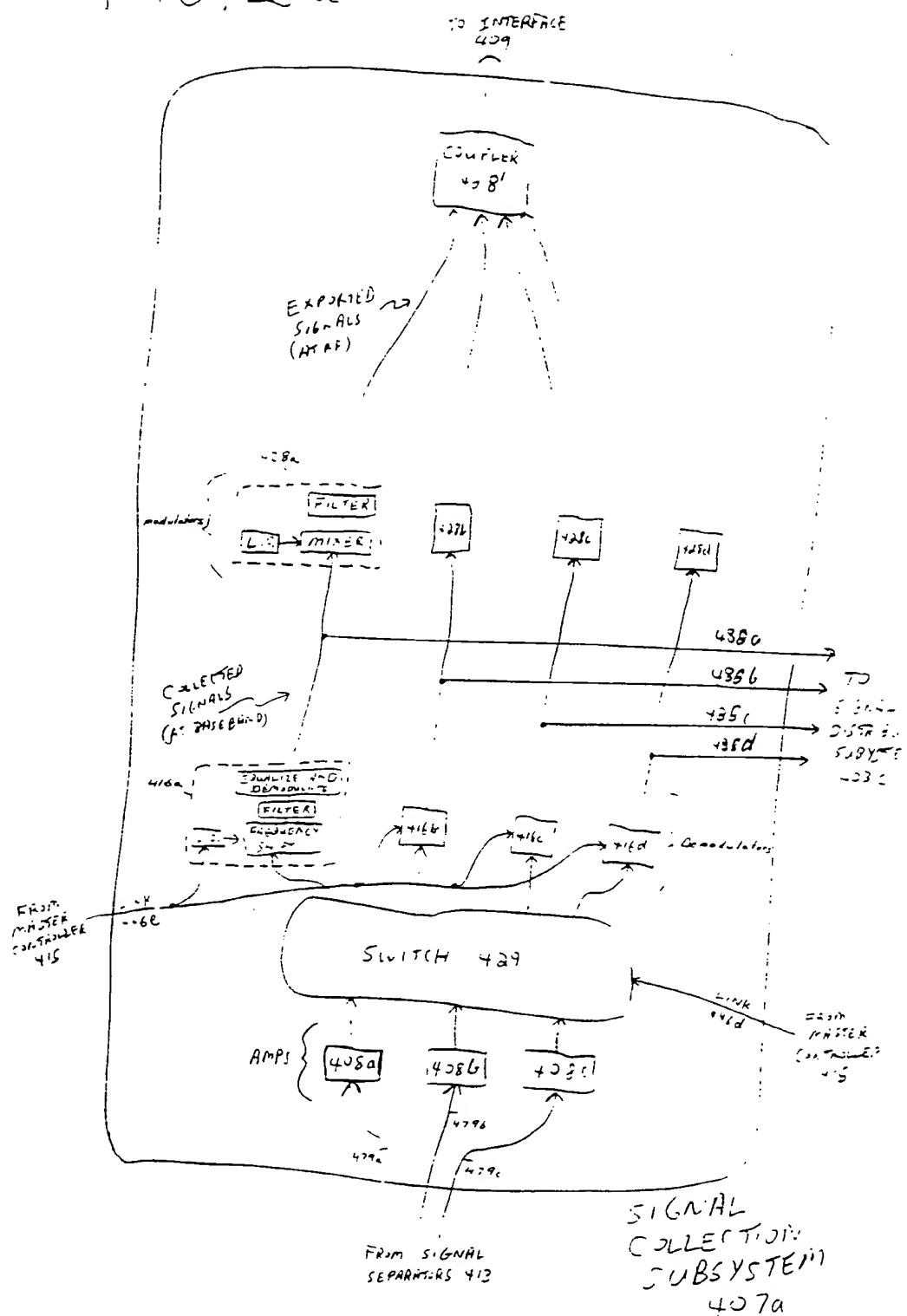
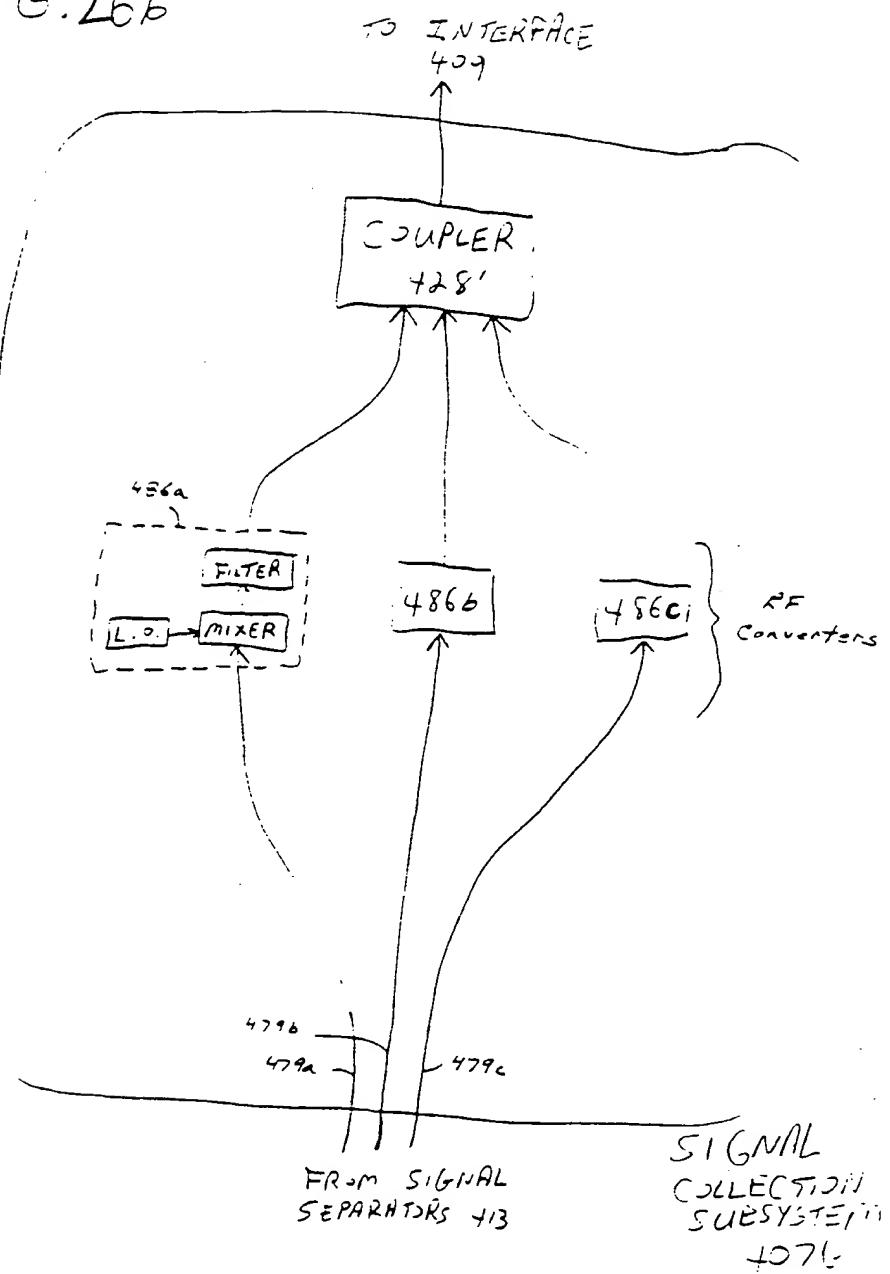


FIG. 26b



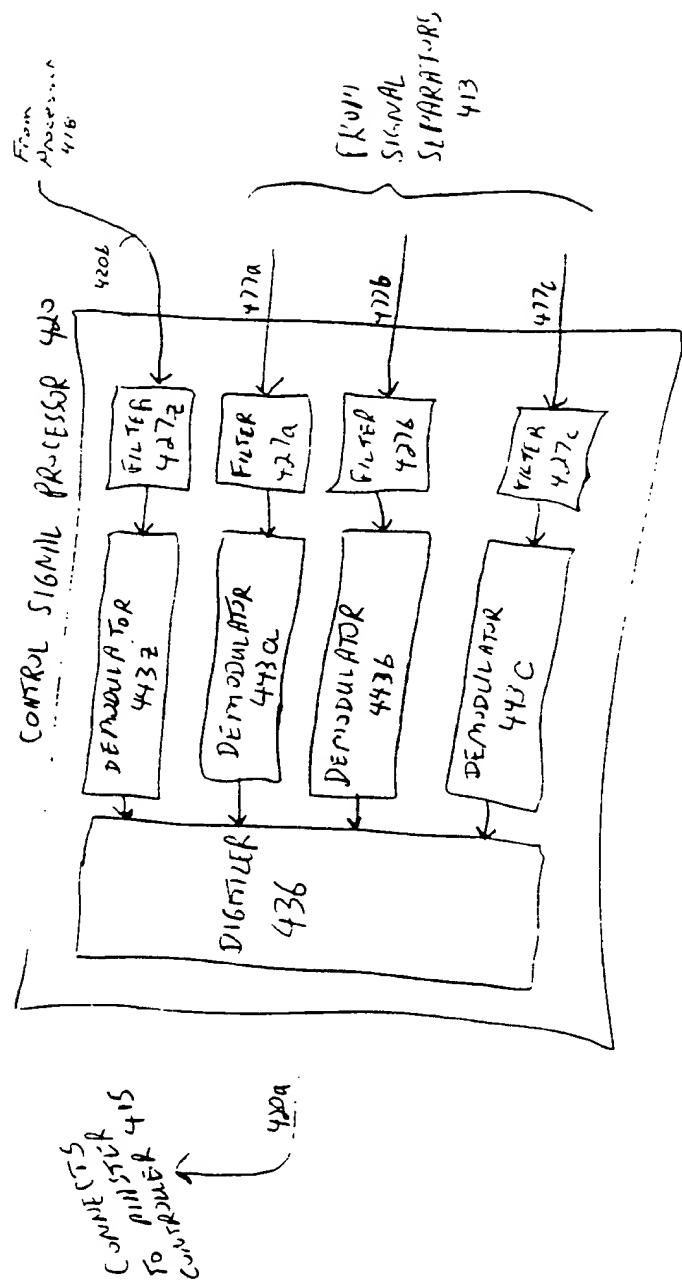


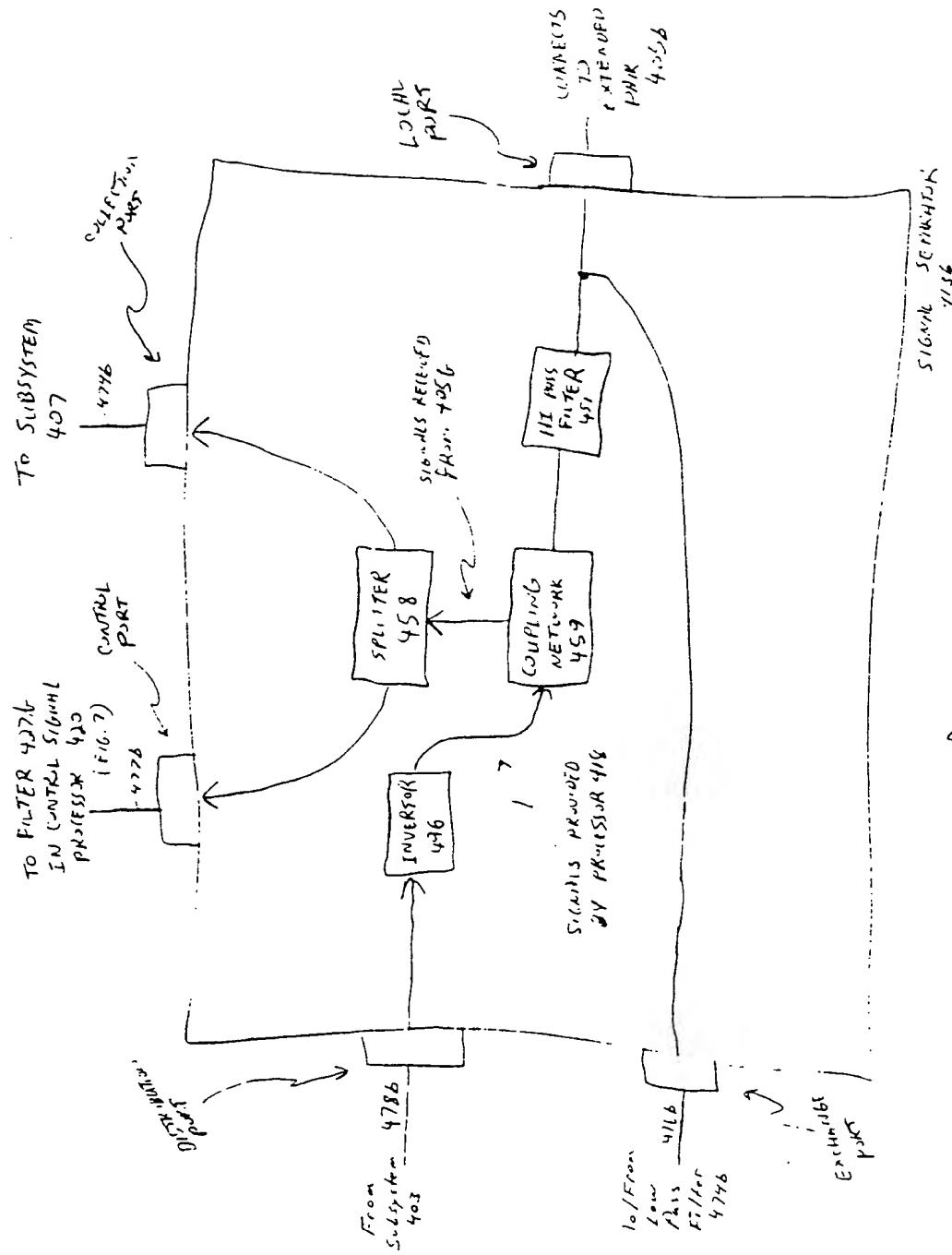
FIGURE 27

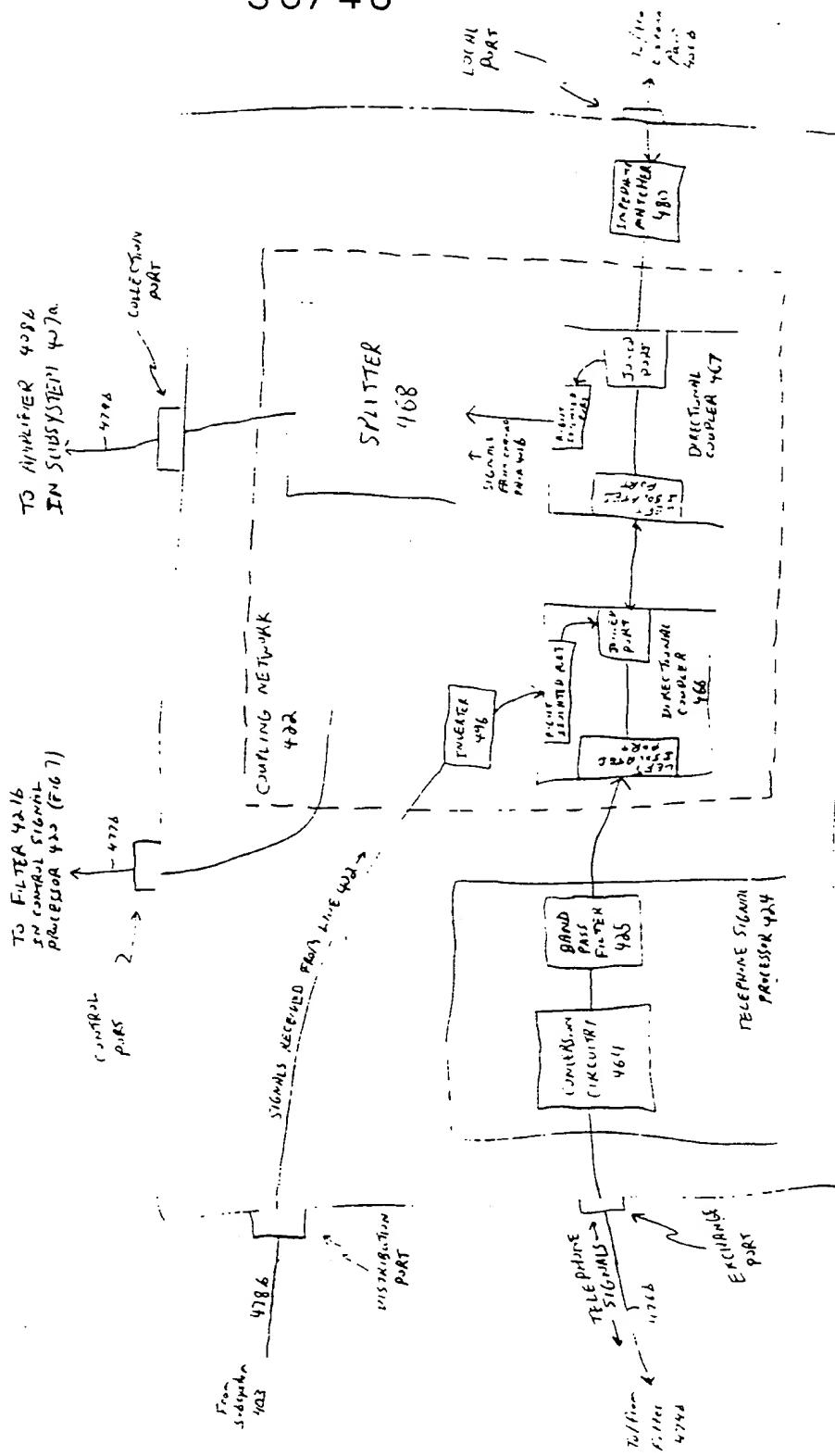
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FREQUENCY DURING
TRANSMISSION OVER
EXTENDED PAIRS (MHz)

ORIGIN/DEST	405a	405b	405c	411a	411b	411c
CONTRL A 493a / 415	22.75-23.25			22.75-23.25		
B 493b / 415		22.75-23.25		22.75-23.25		
C 493c / 415			22.75-23.25		22.75-23.25	
VIDEO U 402 / 492a					12-18 (MHz)	
V 402 / 492b 492c / 402		7-22 (MHz)	1-6 (MHz)	1-6 (MHz)	24-30 (MHz)	54-60 (MHz)
W 494b / 402					24-51 (MHz)	6-12 (MHz)
X 494c / 402						6-12 (MHz)
DIGITAL Y 402 / 495c					6-18	54-100
Z 495c / 402						18-40
						1-6

= 16 - 08

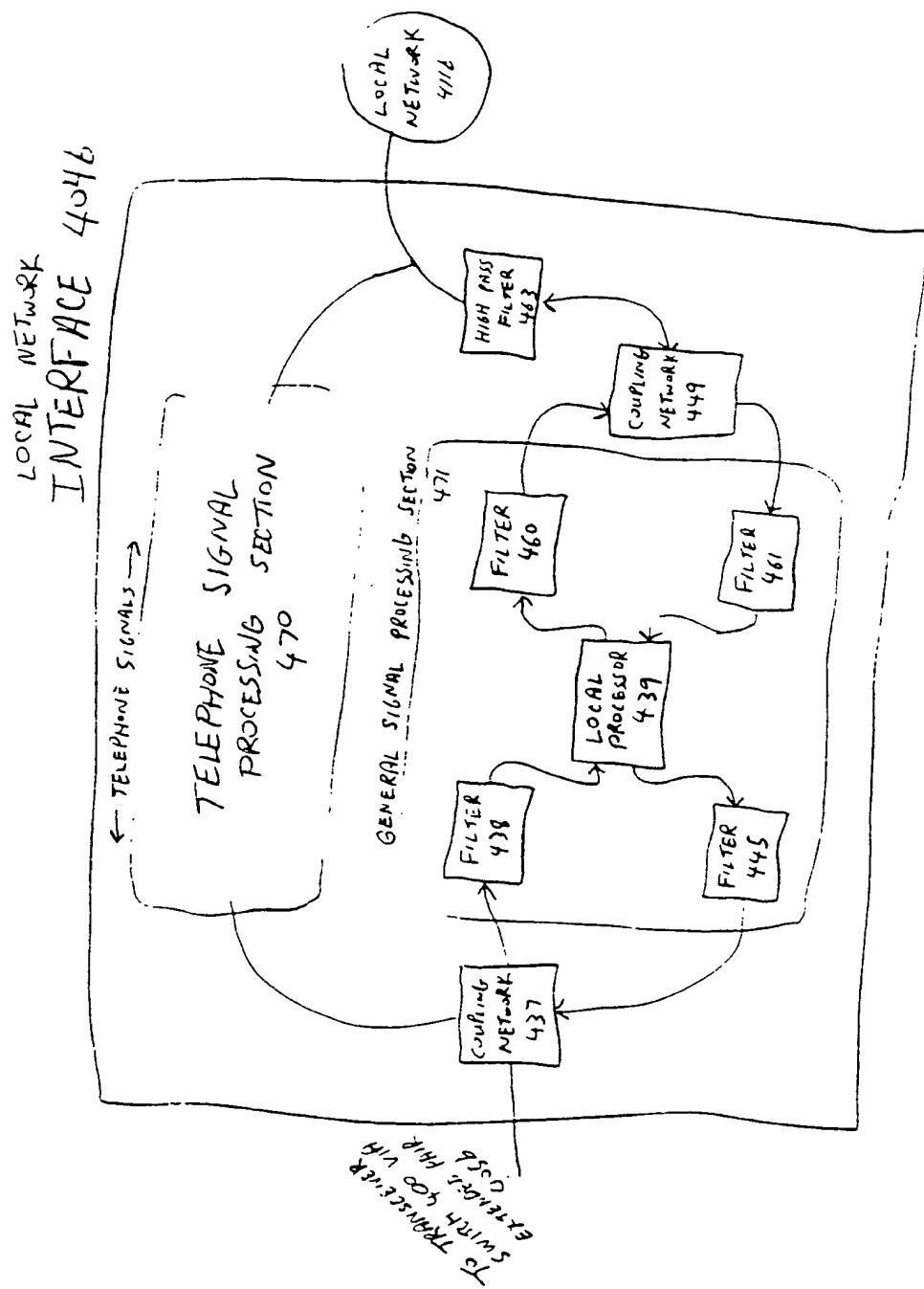




SIGMIL SEPTEMBER
4136

FIG. 29b

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F 16 37

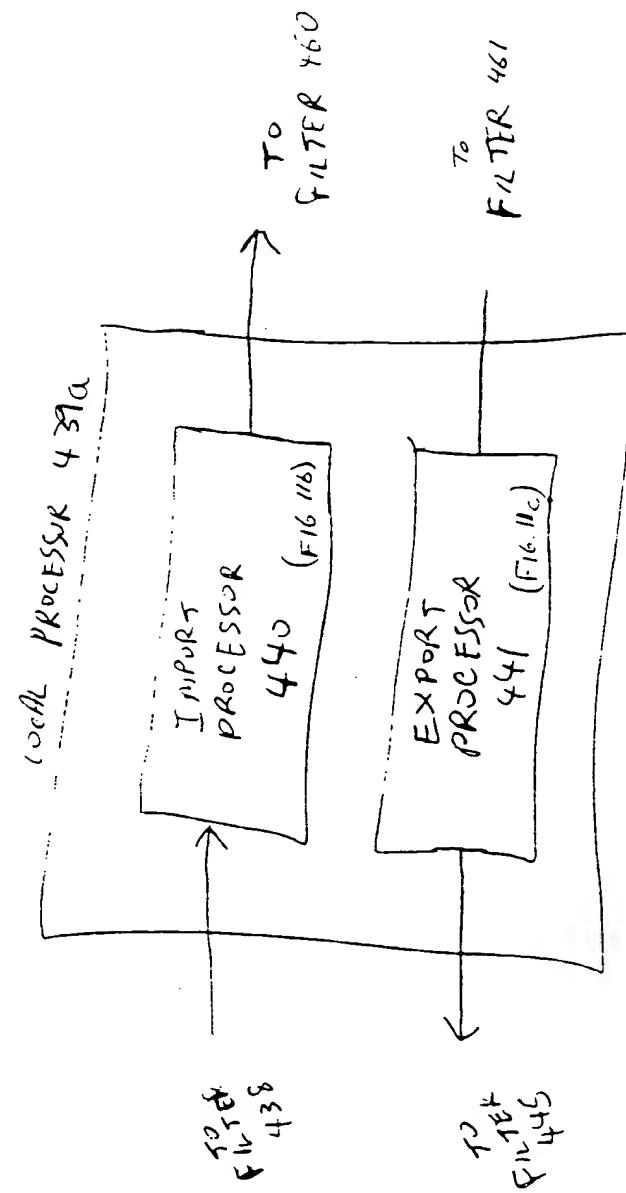


FIG. 31a

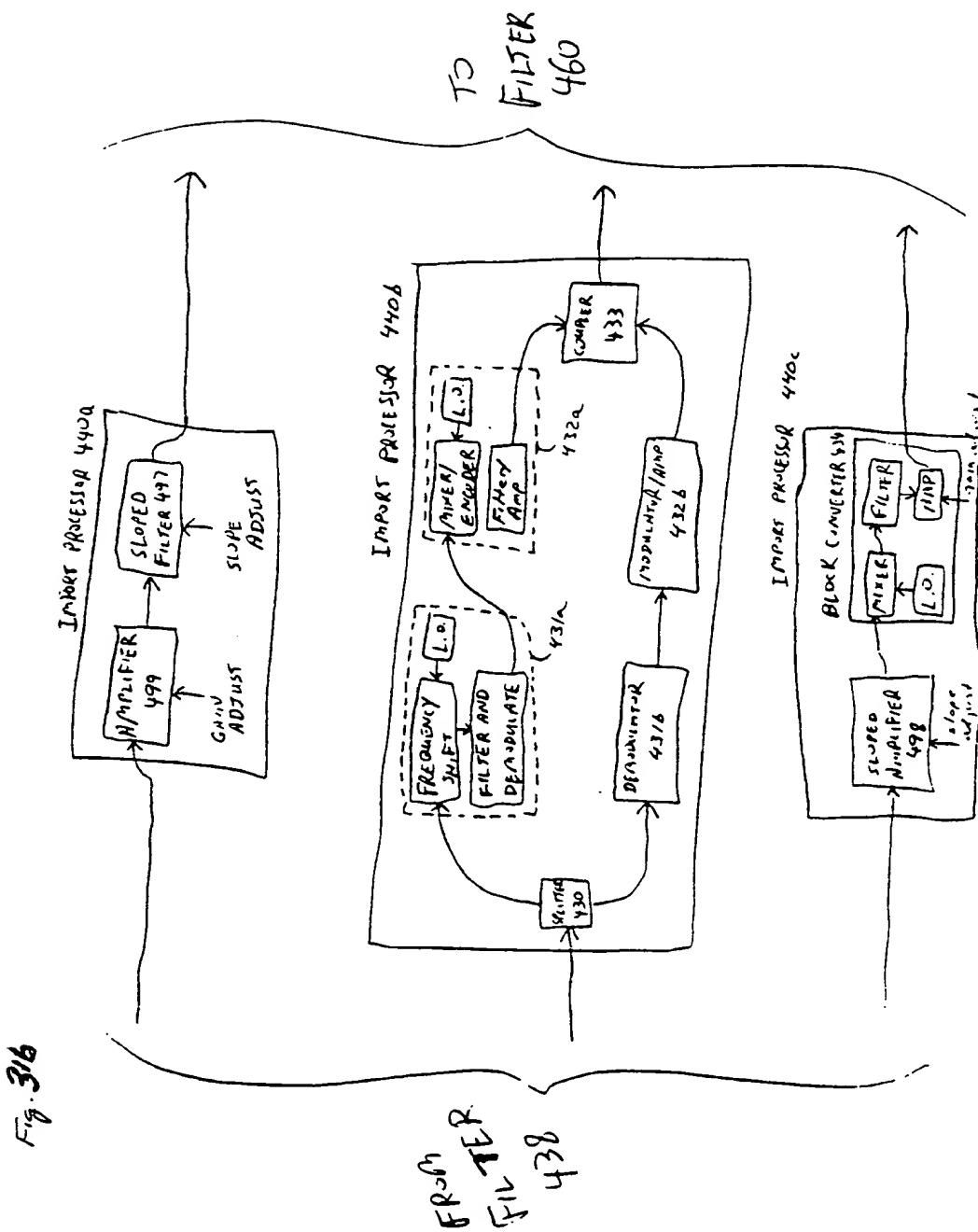
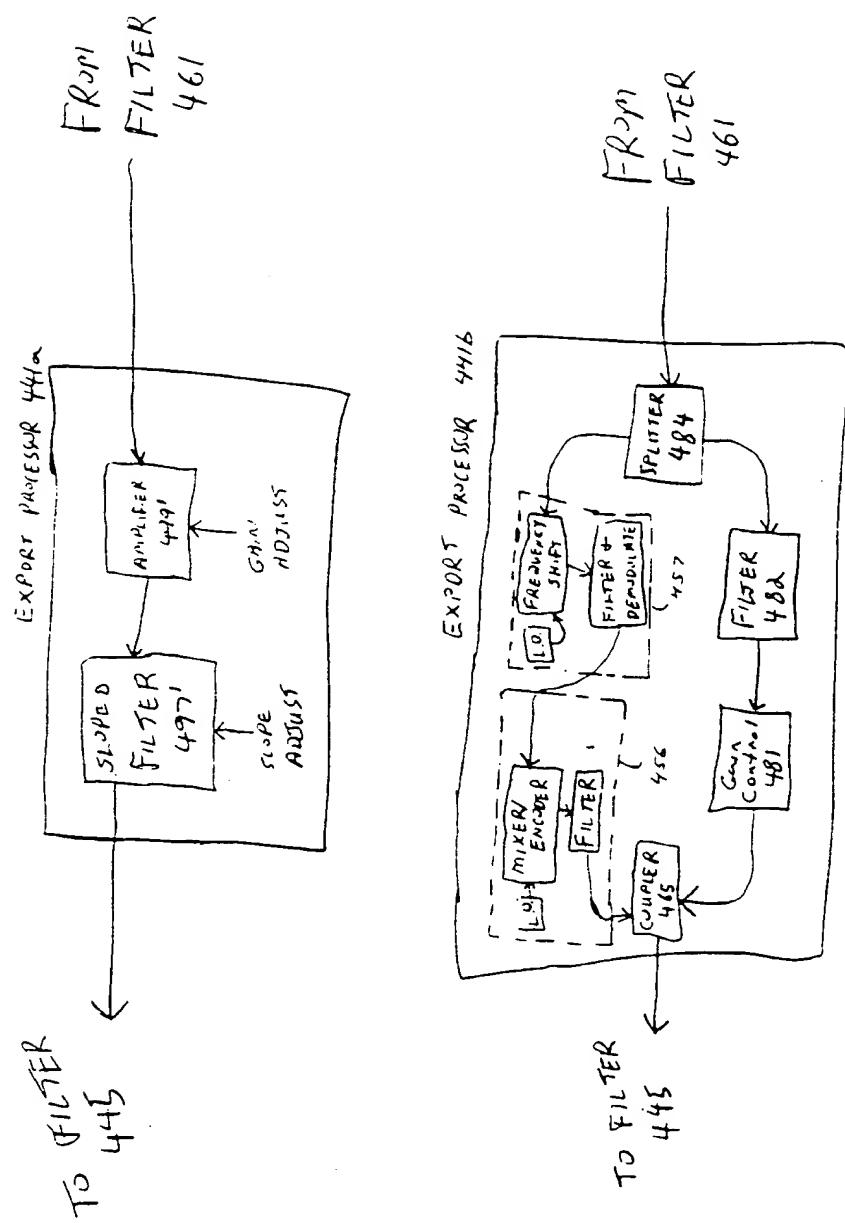


Fig. 3/6

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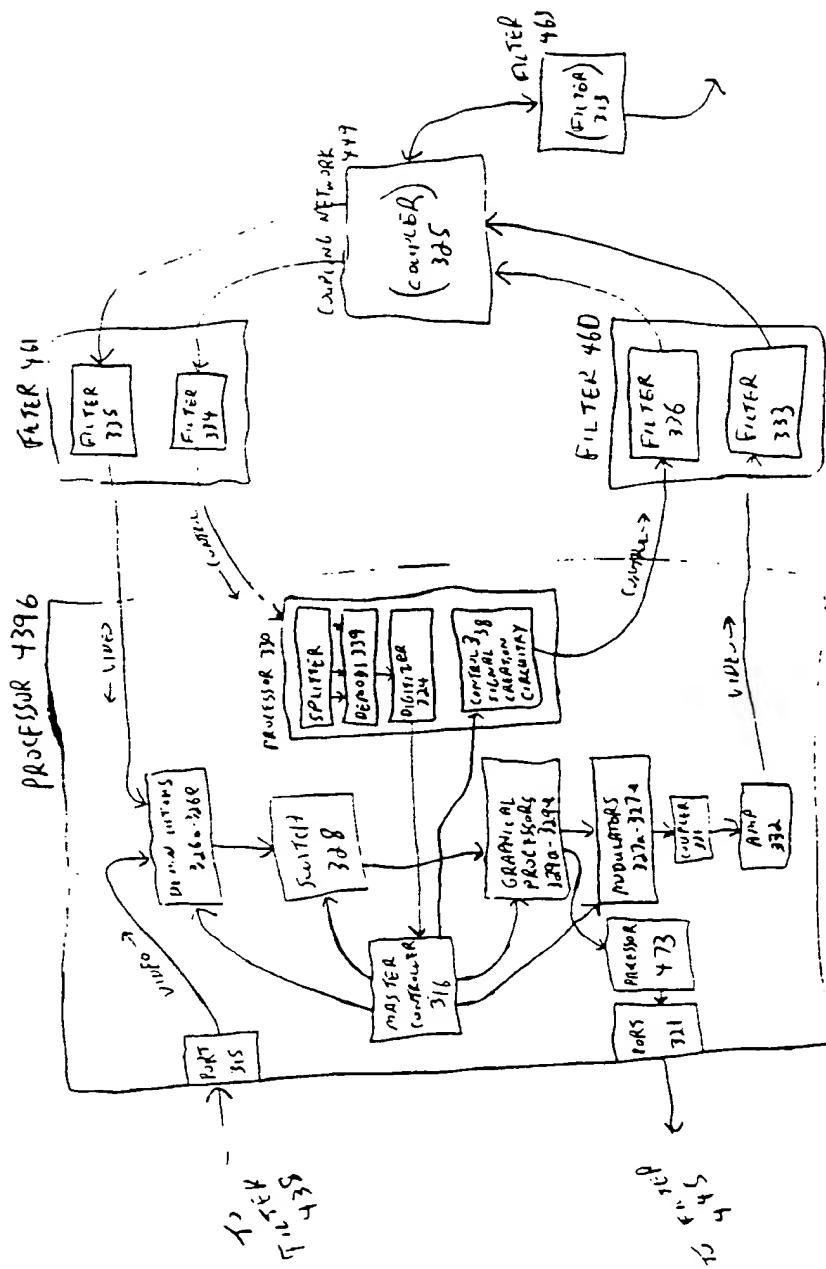
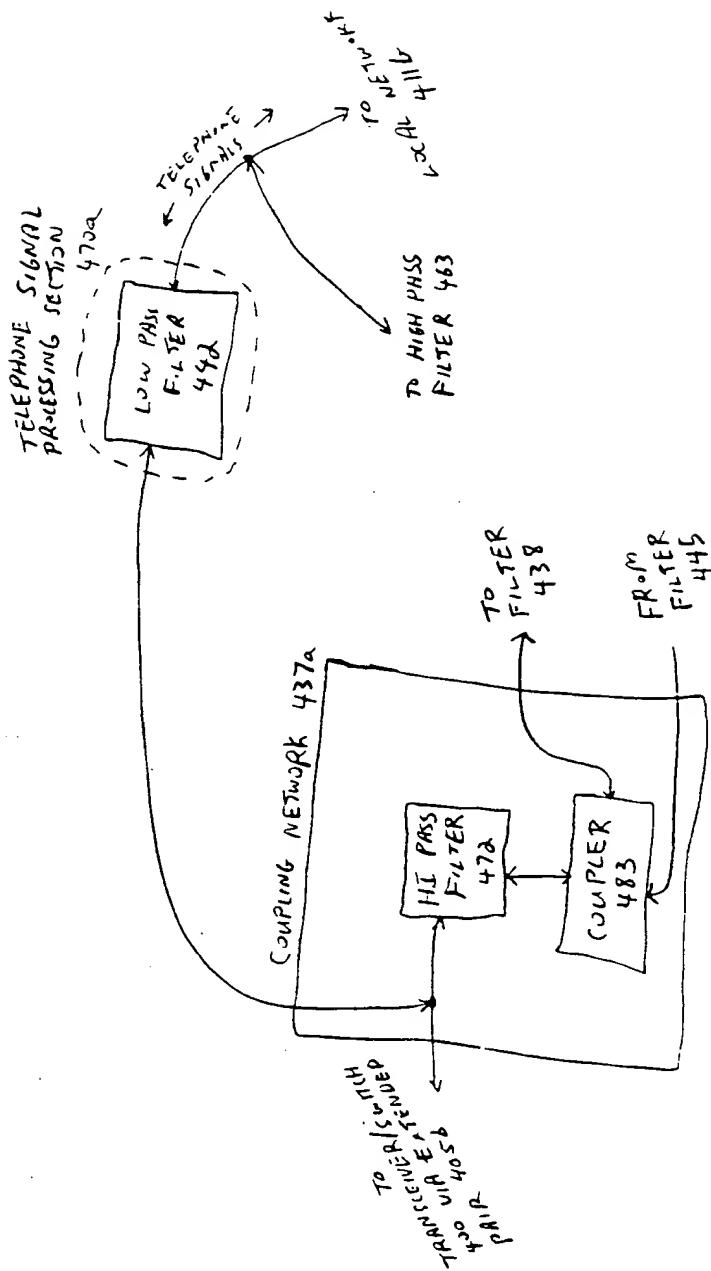


FIG. 32

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F 1 G. 33a

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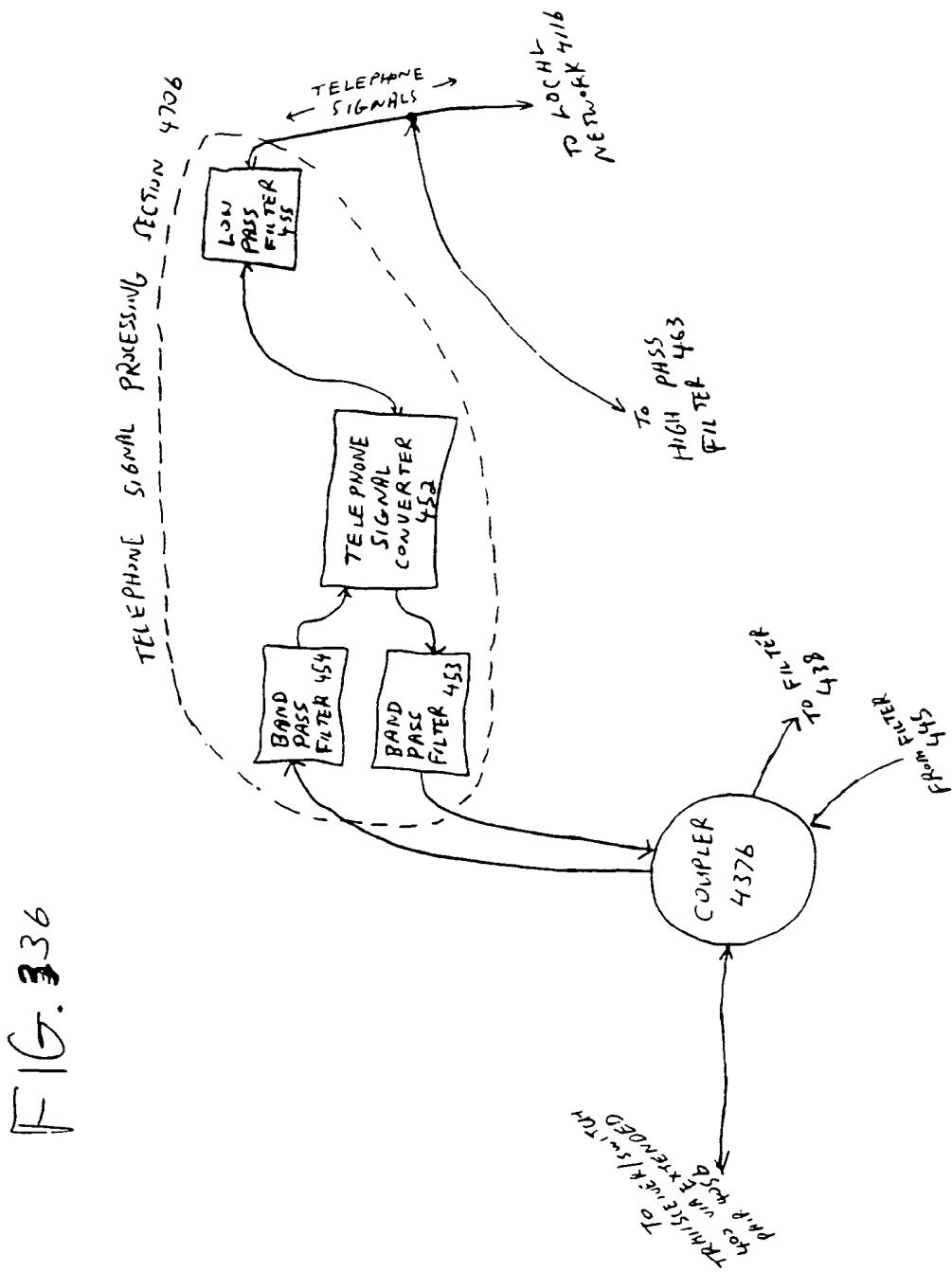


FIG. 336

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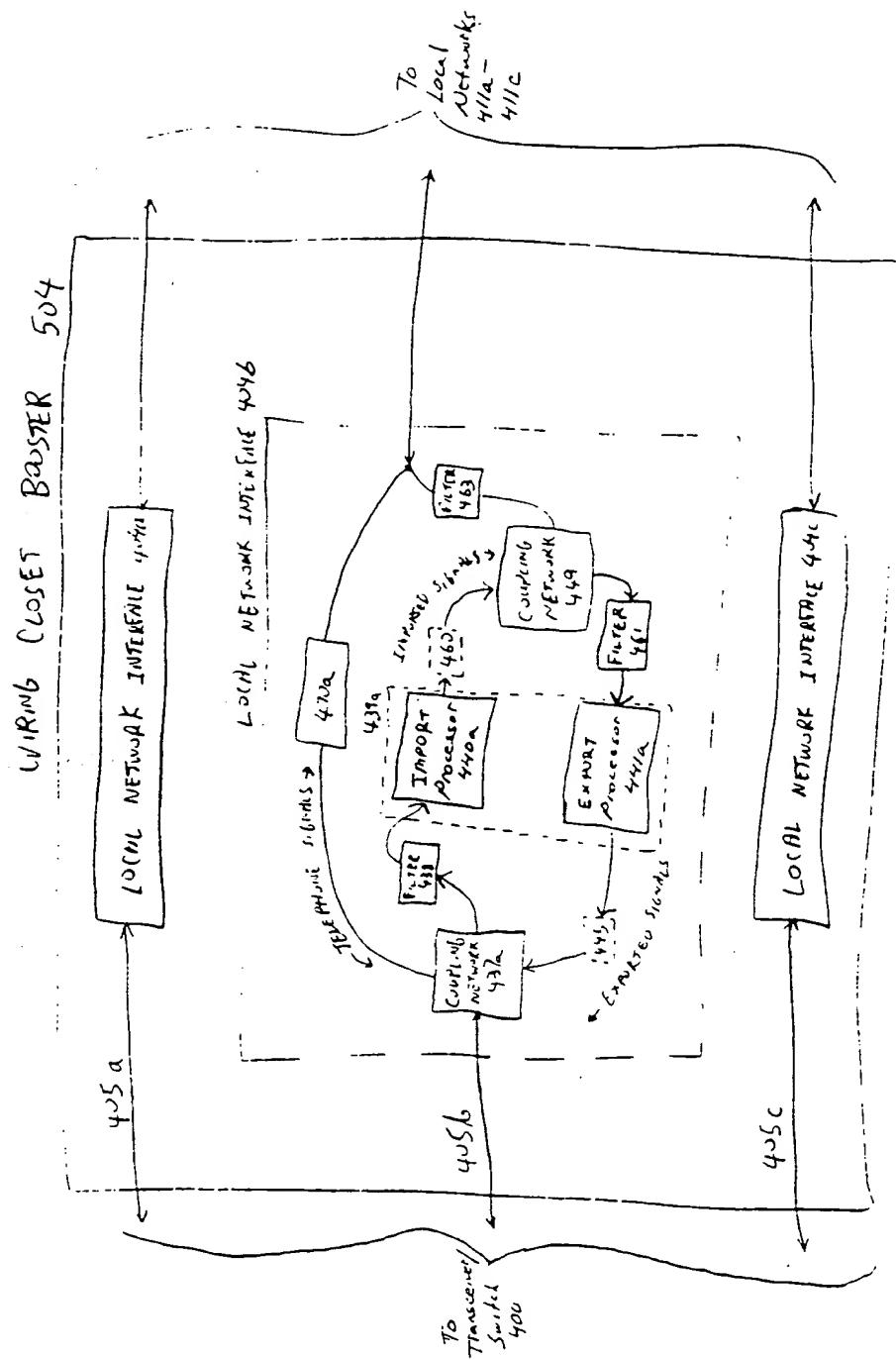


Fig. 34

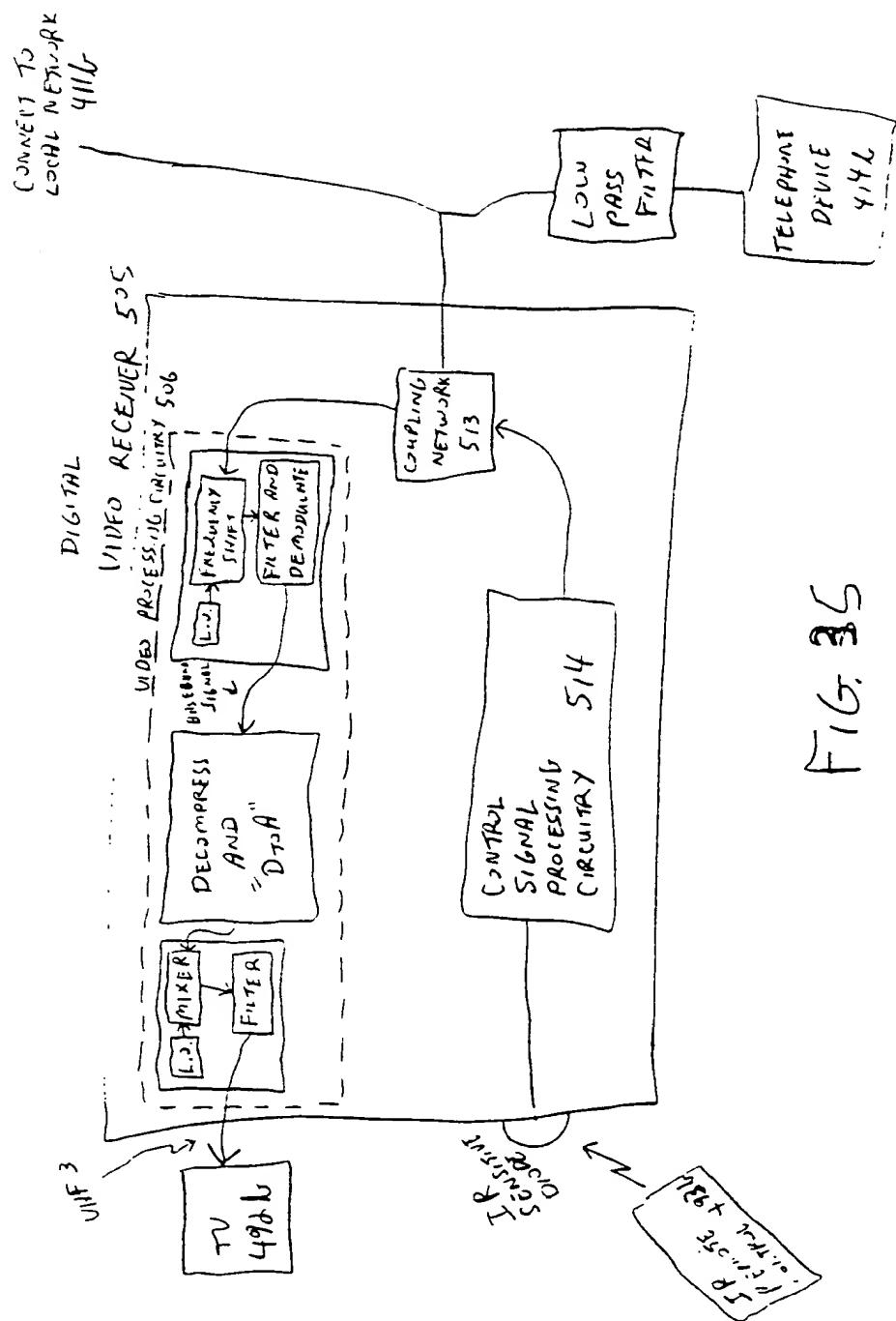
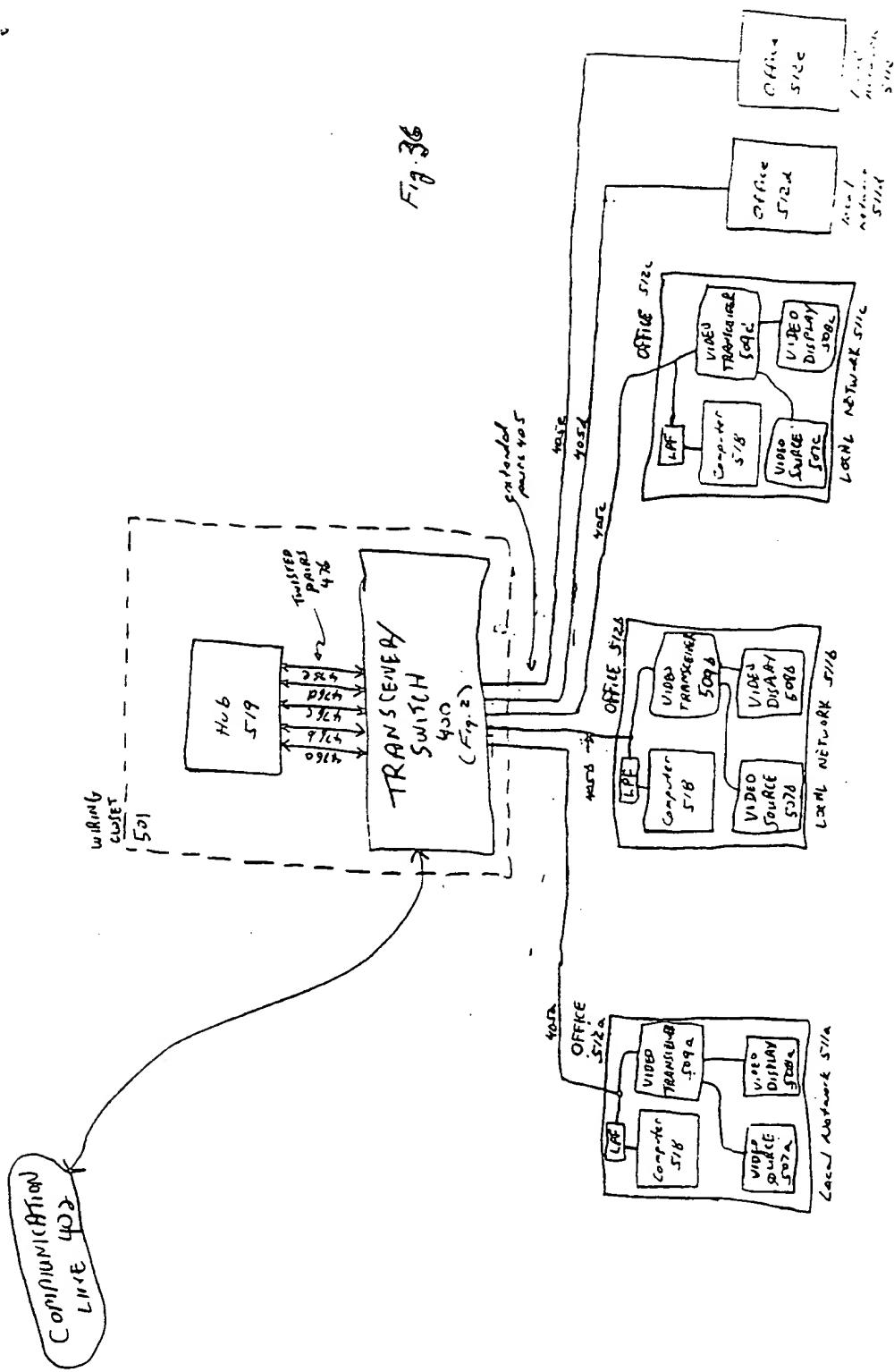


FIG. 35

Fig. 36



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/10330

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) HO4N 7/14

U.S. Class 358/85

Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 379/53,54,64,65,90,101,102,104,105,110,93,96-998; 358/86,194.1; 359/142,145-148; 381/2,3,29,31.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A, 3,723,653 (TATSUZAWA) 27 MARCH 1973 See abstract, all figures	1,2,4,6,8-14, 41-50,54-65,67, <u>68,71-73,77-80</u> 51-53,66,69, 70,74-76
Y	EP,A, 0,244,260 (TWAMURA ET AL) 04 NOVEMBER 1987 See abstract	1,2,4,6,8-14, 41-50,54-65,67, <u>68,71-73,77-80</u> 51-53,66,69,70, 74-76
X		
Y		

 Further documents are listed in the continuation of Box C.

See patent family annex.

Special categories of cited documents:		
A	document defining the general state of the art which is not considered to be part of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E	earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
L	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
O	document referring to an oral disclosure, use, exhibition or other means	*&* document member of the same patent family
P	document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

24 FEBRUARY 1993

Date of mailing of the international search report

28 APR 1993

Name and mailing address of the ISA/US
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Telephone No. (703) 305-4732

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US92/10330

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A, 4,849,811 (KLEINERMAN)	1, 2, 4, 6, 8-14,
Y	18 JULY 1989	41-50, 54-65,
	See abstract, all figures	67, 68, 71-
		<u>73, 77-80</u>
		51-53, 66, 69,
		70, 74-76
Y	WO,A, W088/05974 (GRANDMO U GIN)	1-29, 41-80
	11 AUGUST 1988	
	See abstract	
X	JP,A, 1-27358 (SUZUKI)	<u>1-16, 22-24</u>
Y	30 JANUARY 1989	17-21
	See abstract	

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